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Universal replacement communications satellite

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A practicable universal replacement C band/Ku band communications satellite designed for orbiting the Earth in a storage orbit and a method for its use as a replacement for a failed satellite are disclosed. The universal replacement satellite can be controlled by an external control system (e.g., a ground station) and is reconfigurable by remote command (e.g., from a ground station). The satellite is designed to make several fast moves during its design life from its storage slot to the geostationary slot to which it needs to move when it is to act as a replacement for a failed satellite. The ability to make fast moves helps minimize down time. After its then-current mission of sparing a particular failed satellite has been completed, the communications payload can be turned off and the satellite can be moved back to its storage slot to await its next replacement mission.; Various design features allow it to be able to satisfactorily mimic (that is, emulate) the communications capabilities of a very high percentage of the existing geostationary C band and Ku band satellites while still being economically and otherwise practicable. The satellite can also contain means for handling BSS signals so that the satellite can act as a replacement for both FSS and BSS failed satellites.

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[54]发明名称 通用替换通信卫星

[57]摘要

公开了一种设计用于在储存轨道上绕地球运转的实用的通用替换C波段/Ku波段通信卫星和使用该替换卫星替换失效卫星的方法。该通用替换卫星可以由外部控制系统(例如,地面站)所控制,它可由远程指令(例如来自地面站)重配置。该卫星被设计能在其设计寿命期内从它的储存位置到对地静止位置做几次快速移动,该对地静止位置为当替换卫星替换一颗已失效的卫星时需要它移动到的位置。快速移动的能力帮助减少了故障时间。当替换卫星替换某一失效卫星的临时任务完成后,替换卫星的通信载荷可以关掉,替换卫星可以移动回到它的储存位置等待下一次替换任务。各种设计特征使得替换卫星能够令人满意地模仿(也就是,仿效)现有的对地静止C波段和Ku波段卫星的大部分通性能力,同时,在技术上,经济上和其它方面都是切实可行的。该卫星也能够具有处理BSS信号的装置,使该卫星可充当FSS和BSS失效卫星的替换卫星。

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1. 一种通用替换通信卫星，设计用于在对地静止轨道上绕地球运转，它可被外部控制系统控制，并且是可重配置的，它能够仿效现有的对地静止的 C 波段和 Ku 波段通信卫星的大部分通信性能，因此可以作为现有对地静止卫星的替换卫星，该通用替换卫星被设计来接收上行链路 C 波段信号和 Ku 波段信号，并输出 C 波段和 Ku 波段下行链路信号，该通用替换通信卫星包括：

(a) Ku 波段处理装置，用于：(i)接收位于三个上行链路波段的信道中的 Ku 波段上行链路信号，每一上行链路波段有多个上行链路 Ku 波段信道，（ii）放大信号，（iii）对它们的频率进行下变频，和（iv）输出任何已放大并降频的 Ku 波段信号，作为至少 4 个下行链路 Ku 波段中任一个的信道中的 Ku 波段下行链路信号，每一个下行链路 ku 波段具有多个下行链路 Ku 波段信道；

(b) 两个以上的 Ku 波段下行链路天线，每一个天线能够输出包括 Ku 波段下行链路信号的下行链路波束，每一下行链路波束可单独地指向到地球上不同的地点；

(c) 用于将 Ku 波段下行链路信号导入到所述两个以上的 Ku 波段下行链路天线中的任一个天线的装置；

(d) C 波段处理装置，用于：(i)接收位于至少一个上行链路波段的信道中的 C 波段上行链路信号，每一上行链路波段具有多个上行链路 C 波段信道，（ii）放大信号，（iii）对它们的频率进行下变频，和（iv）输出任何已放大并降频的 C 波段信号，作为至少一个下行链路 C 波段的信道中的 C 波段下行链路信号，每一个下行链路波段有许多下行链路 C 波段信道；

(e) 一个以上的 C 波段下行链路天线，每一个天线能够输出包括下行链路 C 波段信号的下行链路波束，每一下行链路波束可单独地指向地球上不同的地点；

(f) 用于将 C 波段下行链路信号导入到所述一个以上的 C 波段下行链路天线中的任一个的装置；

(g) 推力分系统，使卫星在其设计寿命期中能够做至少两次快速移动；

(h) 电源分系统，为卫星工作提供电源；

(i) 遥测指令分系统，使卫星能够监测自身的状况和与外部控制系统通信；

(j) 姿态和轨道控制分系统，该系统用于帮助将卫星相对地球定位；

(k) 温度控制分系统，该系统帮助将卫星保持在合适的工作温度范围内；以及

(l)重配置卫星的装置。

2. 根据权利要求 1 所述的通用替换卫星，其特征在于，其中的 Ku 波段处理装置用于：（a）接收位于三个 250MHz 上行链路波段的信道中的 Ku 波段上行链路信号，这三个 250MHz 上行链路波段为 13.75-14.0GHz，14.00-14.25GHz 和 14.25-14.50GHz，每一上行链路波段具有多个上行链路 Ku 波段信道，（b）放大信号，（c）对它们的频率进行下变频，和（d）输出任何已放大并降频的 Ku 波段信号，作为 6 个位于 10.95-11.20GHz，11.45-11.70GHz，11.70-12.20GHz 和 12.25-12.75GHz 下行链路 Ku 波段的任一个 250MHz 波段中的信道中的 Ku 波段下行链路信号，每一个下行链路 ku 波段具有多个下行链路 Ku 波段信道。

3. 根据权利要求 2 所述的通用替换卫星，其特征在于，重配置卫星的装置包括：远程调整 Ku 波段处理装置以将一些但不是在一个 Ku 上行链路波段中的所有信号导入到 6 个下行链路 ku 波段中的任一个，并将这个 Ku 上行链路波段中的其它信号导入到 6 个下行链路 ku 波段中相同的或不同的波段的装置。

4. 根据权利要求 3 所述的通用替换卫星，其特征在于，远程调整 Ku 波段处理装置以引导信号的装置包括远程调整 Ku 波段处理装

置，以改变要将信号下变频至的频率的装置。

5. 根据前述的任何一项权利要求所述的通用替换卫星，其特征在于，所述 C 波段处理装置用于：（a）接收两个上行链路波段中信道内的 C 波段上行链路信号，这两个上行链路波段位于 5.925 到 6.425GHz 和 6.425 到 6.725GHz，每一个上行链路波段有多个上行链路 C 波段信道，（b）放大信号，（c）对它们的频率进行下变频，和（d）输出那些已放大并降频的 C 波段信号，作为位于 3.70-4.20GHz 和 3.40-3.70GHz 下行链路 C 波段信道内的 C 波段下行链路信号，每一个下行链路 C 波段有多个下行链路 C 波段信道。

6. 根据前述的任何一项权利要求所述的通用替换卫星，其特征在于，（a）有两个以上的 C 波段下行链路天线，每一个天线能够输出包括有下行链路 C 波段信号的下行链路波束，每一个下行链路波束可独立地指向地球上的不同地点，和（b）有将 C 波段下行链路信号引入到两个以上的 C 波段下行链路天线中任一个天线的装置。

7. 根据前述的任何一项权利要求所述的通用替换卫星，其特征在于，所述推力分系统被设计为使卫星能够在其设计寿命中做至少 3 次快速移动，每一次快速移动以至少每天 3 度移动。

8. 根据前述的任何一项权利要求所述的通用替换卫星，其特征在于，遥测指令分系统包括至少能在两种不同频率上发送信号的遥测子系统和至少可以在两种不同频率上接收信号的指令子系统。

9. 根据前述的任何一项权利要求所述的通用替换卫星，其特征在于，用于重配置卫星的装置包括：（a）用于远程调整 Ku 波段处理装置，以将具有至少 2 路但少于每一个上行链路 Ku 波段中的所有信号的包导入到任一个下行链路 Ku 波段的装置，（b）用于远程调整来自至少一个 Ku 波段下行链路天线的下行链路波束以将波束指向地球

上不同的地点的装置，（c）用于远程调整来自至少一个以上的 C 波段下行链路天线中的一个天线的下行链路波束以将波束指向地球上不同地点的装置，（d）用于远程改变来自至少一个下行链路天线的下行链路波束的覆盖区域的装置，和（e）用于远程改变至少一个下行链路天线的极性的装置。

10. 根据权利要求 1，2 和 5-9 中的任一项所述的替换卫星，其特征在于，用于重配置卫星的装置包括如下装置：该装置用于远程调整 Ku 波段处理装置以将一个 Ku 上行链路波段中的一些而不是全部信号导入到至少 4 个下行链路 Ku 波段中任一个波段，并将这一个 Ku 上行链路波段中的其它信号导入到至少 4 个下行链路 Ku 波段中的相同或不同波段。

11. 根据权利要求 10 所述的替换卫星，其特征在于，用于远程调整 Ku 波段处理装置，以引导信号的装置包括：远程调整 Ku 波段处理装置以改变信号要降频到的频率的装置。

12. 根据前述的任何一项权利要求所述的替换卫星，还包括一个以上的上行链路 C 波段天线和一个以上的上行链路 Ku 波段天线，所有的上行链路天线可被独立地操作指向地球的不同地点。

13. 根据前述的任何一项权利要求所述的替换卫星，其特征在于，上行链路天线也作为下行链路天线工作。

14. 根据前述的任何一项权利要求所述的替换卫星，其特征在于，它被设计使得在卫星设计寿命的末期，至少 24 路上行链路 Ku 波段信道的信号能够被 Ku 波段处理装置处理，至少 24 路上行链路 C 波段信道的信号能被 C 波段处理装置处理。

15. 根据前述的任何一项权利要求所述的替换卫星，还包括用于

远程改变来自至少一个 Ku 波段下行链路天线的下行链路波束的覆盖区域的装置。

16. 根据前述的任何一项权利要求所述的替换卫星，其特征在于，推力系统被设计为使卫星在其设计寿命期内能做至少 3 次快速移动，每次以至少每天 5 度移动。

17. 根据前述的任何一项权利要求所述的替换卫星，其特征在于，卫星被这样设计以使在卫星设计寿命的初期，至少 32 路上行链路 Ku 波段信道的信号能被 Ku 波段处理装置处理，至少 32 路上行链路 C 波段信道的信号能被 C 波段处理装置处理。

18. 根据前述的任何一项权利要求所述的替换卫星，其特征在于，所有的 Ku 波段信道具有标准的带宽。

19. 根据权利要求 18 所述的替换卫星，其中标称带宽为标称的 36MHz。

20. 根据前述的任何一项权利要求所述的替换卫星，还包括 BSS 波段处理装置，该装置包括一种装置，用于：（a）接收位于从 17.3GHz 到 18.1GHz 频率范围内的 BSS 上行链路信号，（b）放大 BSS 信号，（c）对它们的频率进行下变频，和（d）输出那些已放大并降频的 BSS 波段信号，作为提供给下行链路 Ku 波段信号的波段的信道中的 BSS 下行链路信号。

21. 一种设计为在对地静止的轨道上绕地球运行的通用替换通信卫星，其可以由外部控制系统控制，能够重新配置，能够仿效已有的对地静止的 C 波段和 Ku 波段通信卫星的大部分通信性能，也因此此卫星可作为被替换卫星的替换，该通用替换卫星被设计用于接收上行链路 C 波段和 Ku 波段信号并输出 C 波段和 Ku 波段下行链路信号，

该通用替换卫星包括：

(a) Ku 波段处理装置，用于(i)接收 Ku 波段上行链路信号，该信号位于三个 250MHz 上行链路波段的信道中，这三个波段为，13.75-14.00GHz,14.00-14.25GHz 和 14.25-14.50GHz，每一上行链路波段有多个上行链路 Ku 波段信道，（ii）放大信号，（iii）对它们的频率进行下变频，和（iv）输出任何已放大并降频的 Ku 波段信号，作为 6 个 250MHz 波段的信道里的 Ku 波段下行链路信号，这 6 个 250MHz 波段位于 10.95-11.20GHz,11.45-11.70GHz,11.70-12.20GHz, 和 12.25-12.75GHz 下行链路 Ku 波段中，每一个下行链路 ku 波段有多个下行链路 Ku 波段信道；

(b) 两个以上的 Ku 波段下行链路天线，每一个天线能够输出包括 Ku 波段下行链路信号的下行链路波束，每一下行链路波束可单独地指向地球上不同的地点；

(c) 用于将 Ku 波段下行链路信号引入到两个以上的 Ku 波段下行链路天线中的任一个天线的装置；

(d) C 波段处理装置，用于(i)接收位于两个上行链路波段信道中的 C 波段上行链路信号，这两个上行链路波段为 5.925 到 6.425GHz 和 6.425 到 6.725GHz，每一上行链路波段有多个上行链路波段信道，（ii）放大信号，（iii）对它们的频率进行下变频，和（iv）输出任何已放大并降频的 C 波段信号，作为 3.70-4.20GHz 和 3.40-3.70GHz 下行链路 C 波段信道内的 C 波段下行链路信号，每一个下行链路 C 波段具有多个下行链路 C 波段信道；

(e) 两个以上的 C 波段下行链路天线，每一个天线能够输出包括下行链路 C 波段信号的下行链路波束，每一下行链路波束可单独地指向地球上不同的地点；

(f) 用于将 C 波段下行链路信号引入到两个以上的 C 波段下行链路天线中的任一个天线的装置；

(g) 推力分系统，设计使得在卫星的设计寿命期中卫星能够做至少 3 次快速移动,每一次快速移动达到每天至少 3 度；

(h) 电源分系统为卫星工作提供电源；

(i) 遥测指令分系统,使卫星能够监测自身的状况和与外部控制系统通信，该分系统包括至少能在两个不同频率上发送信号的遥测子系统和至少可以在两个不同频率上接收信号的指令子系统；

(j) 姿态和轨道控制分系统，该分系统用于帮助将卫星相对地球定向；

(k) 温度控制分系统，该分系统帮助维持卫星在一个合适的工作温度范围内；和

(l) 重新配置卫星的装置，该装置包括(i) 远程调整 Ku 波段处理装置的装置，将至少 2 路但少于每一上行链路 Ku 波段中的所有信号的包引入到任一下行链路 Ku 波段中，（ii）用于远程调整来自至少一个 Ku 波段下行链路天线的下行链路波束，以将该波束指向地面上的不同位置的装置，（iii）用于远程调整来自至少一个 C 波段下行链路天线的下行链路波束，以将该波束指向地球上的不同位置的装置，（iv）用于远程改变来自至少一个下行链路天线的下行链路波束的覆盖区域的装置，（v）用于远程改变至少一个下行链路天线的极性的装置。

22. 一种被设计为在对地静止的轨道上绕地球运行的通用替换通信卫星，其可以由外部控制系统控制，能够重新配置，能够仿效已有的对地静止的 C 波段和 Ku 波段通信卫星的大部分通信性能，从而该卫星可作为替换卫星，该通用替换卫星被设计用于接收上行链路 C 波段和 Ku 波段信号，并输出 C 波段和 Ku 波段下行链路信号，该通用替换卫星包括：

(a) Ku 波段处理装置，用于(i)接收 Ku 波段上行链路信号，该信号位于三个 250MHz 上行链路波段的信道中，这三个波段为，13.75-14.00GHz，14.00-14.25GHz 和 14.25-14.50GHz，每一上行链路波段有多个上行链路 Ku 波段信道，（ii）放大信号，（iii）对它们的频率进行下变频，和（iv）输出任何已放大并降频的 Ku 波段信号，作为 6 个 250MHz 波段信道里的 Ku 波段下行链路信号，这 6 个 250MHz 波段位于 10.95-11.20GHz，11.45-11.70GHz，11.70-12.20GHz 和 12.25-12.75GHz 下行链路 Ku 波段中，每一个下行链路 ku 波段有多个下行

链路 Ku 波段信道；

(b) 两个以上的 Ku 波段下行链路天线，每一个天线能够输出包括 Ku 波段下行链路信号的下行链路波束，每一下行链路波束可单独地指向地球上不同的地点；

(c) 用于将 Ku 波段下行链路信号引入到两个以上的 Ku 波段下行链路天线中的任一个天线的装置；

(d) C 波段处理装置，用于(i)接收位于两个上行链路波段信道中的 C 波段上行链路信号，这两个上行链路波段约在 5.925 到 6.425GHz 和 6.425 到 6.725GHz 之间，每一上行链路波段有多个上行链路 C 波段信道，（ii）放大信号，（iii）对它们的频率进行下变频，和（iv）输出任何已放大并降频的 C 波段信号，作为 3.70-4.20GHz 和 3.40-3.70GHz 下行链路 C 波段信道内的 C 波段下行链路信号，每一个下行链路 C 波段有多个下行链路 C 波段信道；

(e) 两个以上的 C 波段下行链路天线，每一个天线能够输出包括 C 波段下行链路信号的下行链路波束，每一下行链路波束可单独地指向地球上不同的地点；

(f) 用于将 C 波段下行链路信号传送到两个以上的 C 波段下行链路天线中的任一个天线的装置；

(g) 推力分系统，其设计使得在卫星的设计寿命期中卫星能够做至少 3 次快速移动；

(h) 电源分系统，为卫星工作提供电源；

(i) 遥测指令分系统,使卫星能够监测自身的状况和与外部控制系统通信；

(j) 姿态和轨道控制分系统，该系统用于帮助将卫星相对地球定向；

(k) 温度控制分系统，该系统帮助维持卫星在一个合适的工作温度范围内；和

(l) 重新配置卫星的装置。

23. 一种替换处理 C 波段和 Ku 波段信号的相对地面静止的通信

卫星的方法，该方法包括：提供前述任何一项权利要求的通用替换通信卫星，将替换卫星放置于适合的对地静止位置，重新配置卫星以仿效被替换卫星的通信性能。

24. 根据权利要求 23 所述方法，还包括将卫星放置于储存轨道并通过组合漂移和倾角操作将替换卫星从它的储存轨道移动到适合的相对地面静止位置。

说　明　书

通用替换通信卫星

技术领域

本发明涉及通信卫星领域，特别涉及提供一种切实可行的卫星的技术问题，对大多数在轨的固定卫星业务通信卫星，也希望对于大多数将要安置在轨道上的这种卫星来说，该卫星可充当令人满意的替换卫星。

技术背景

通信（或电信）卫星已经应用了多年。上行链路信号从一个以上的地面站发出，被卫星上一个以上的上行链路天线接收，经过卫星内的电路处理（例如频移和放大），再从卫星上的一个以上的下行链路天线发送回地面，被一个以上的地面站接收。卫星可以定位在环绕地球的不同轨道上。对于特定的通信卫星而言，一特别可取的轨道是赤道轨道（也就是大致位于地球赤道平面内），其高度约为 22300 英里（大约 36000 公里）。在此高度的轨道上，卫星绕地球的运行周期与地球自转周期相同。因此，从地球上发射（上行链路）站和接收（下行链路）站看，卫星停留在天空中的固定点，因而卫星可被认为在同步赤道轨道上或说是对地静止的。因此，对地静止卫星位置可用其赤道经度来定义。例如，用于向美国大陆及其领土广播的卫星可能位于大约西经 69°到大约西经 139°之间。

使用对地静止的卫星的优点之一是，地球上的发射和接收站无需追踪在空中事先选定轨道位置的卫星以维持所需的上行链路和下行链路通信特征(卫星受到的信号的强度,地球上的下行链路信号的覆盖区域等)。换句话说，对地静止的卫星的天线可为固定的（静止的），下行链路的覆盖区域也是固定的。

除了有固定的天线的典型特征外，典型地，对地静止卫星被设计用于根据上行链路频率方案，从地球上预先指定的一个以上的地理区域在预先选定的频率波段（上行链路波段）上接收特定的信号，将信号放大到要求的功率，依据下行链路规划在其它预先选定的频率波段（下行链路波段）上将信号重发射至地球上的预先选定的一个以上的地理区域。

不幸的是，众所周知，在卫星发射过程中，存在发生故障和完全失败的极大可能性，即使发射成功后，在将卫星布置到合乎需要的轨道位置时可能会有问题。卫星被成功定位且工作一段时间后，也可能发生失效。这种失效包括突发性的和逐渐性的，部分的或全部的失去通性能力。

考虑到在整个预期寿命周期内，在轨道上没有一颗完全正常工作的通信卫星运转而造成的严重经济损失，希望提供能够恢复失效卫星的通信功能的替换卫星（也就是备用卫星）。替换卫星可储存于轨道上或地面上，每一种储存方式都有它的优点和缺点。不论采用何种储存方式，出于费用，重量和其它方面的考虑，典型地，将替换卫星设计用于与它被设计用于备用的卫星相同的上行链路和下行链路频率规划，功率，覆盖区域和遥测指令系统频率等。

备用卫星的实际成本要耗费卫星通信信道提供者相当的费用（如，拥有卫星并出租它们的信道用于重发射的组织）。这一点千真万确，因为备用卫星也许从不需用到。因此，如果这些提供者能够避或至少显著地减少这些费用将是极其有利的。

人们已提出了各种各样的提供备用卫星的方法。参见，如美国专利 3,995,801，5,120,007，和 5,813,634。涉及或提及备用卫星、备用覆盖区域和/或代替正失效或已失效的卫星的其它文献包括 US 4,502,051，US 5,289,193，US 5,410,731 和 PCT WO 98/04017。涉及到

通信卫星，包括卫星群的通信系统，通信卫星子系统及其部件以及操作通信卫星和系统的方法的其它文献包括：美国专利 4,688,259；4,858,225；4,965,587；5,020,746；5,175,556；5,297,134；5,323,322；5,355,138；5,523,997；5,563,880；5,860,056；和 5,890,679；EPO 公开申请 EP0915529Al；F.Rispoli，“可重配置的卫星天线：评述”（“Reconfigurable Satelite Antennas：A Review”），《电子工程》（Electronic Engineering），第 61 卷，第 748 期，第 S22-S27 页（1989 年 4 月）；和《电子工程师手册》（Electronic Engineers' Handbook），22-63 章，“卫星通信系统”（“Satellite Communications Systems”）第 22-61 至 22-62 页（1975 年）。

上述那些文献中的一些文献涉及了移动天线。参见，如 EP 0 915 529Al。那些中的一些文献涉及到可重配置卫星。参见，例如 US 4,688,259；US 4,858,225；US 4,965,587；US 5 ,175,556；US 5,289,193；US 5,355,138；PCT WO 98/04017；EP 0 915 529Al；和 F.Rispoli：“可重配置卫星天线：评述”（“Reconfigurable Satellite Antennas：A Review”），《电子工程》（Electronic Engineering），第 61 卷，第 748 期，第 S22-S27 页（1989 年 4 月）。上述一些文献涉及到移动卫星，例如将卫星从一位置移动到另一位置或为了位置保持而移动卫星。参见，US5,020,746；US 5,813,634；和 PCT W 0 98/04017。

技术人员已经考虑到为基本上所有的 FSS（C 波段/Ku 波段）通信卫星设计完美的备用（或复制）卫星的替换卫星，但是迄今所知，也许由于这样的卫星是不切实可行的和/或这样的卫星费用太过昂贵，这样的替换卫星从未被制造过。问题在于提供这样的卫星把事情搞更复杂了，事实上，传统的 C 波段/Ku 波段通信卫星涉及到各种不同的特征，例如，所使用的上行链路频率和下行链路频率，功率，覆盖区域版图。而且，以前已发射并置于轨道上的卫星被设计用于特别的轨道位置，这种卫星有相邻的卫星，相邻卫星具有已知的遥测指令系统频率和其它特征。

因此，长期存在且仍未解决的技术问题是，提供切实可行且令人满意的用于 C 波段/Ku 波段通信卫星（FSS 卫星）的备用卫星，换句话说，提供切实可行的 C 波段/Ku 波段备用卫星来解决一长期存在且仍未解决的技术问题，这颗备用卫星能够完成在轨的 C 波段/Ku 波段通信卫星的大部分的（更好地，达到一个很高的百分比）的功能，同时在技术上，经济上和其它方面都是切实可行的。

发明内容

我们现已开发了解决上述技术问题的发明。广而言之，一方面，本发明涉及到一种通用替换通信卫星，这种通信卫星被设计为在对地静止的轨道上绕地球运行，它被外部控制系统控制，能够重新配置，能够完成已有的对地静止的 C 波段/Ku 波段通信卫星和它能替换的通信卫星的大部分的通信功能，该通用替换卫星被设计用于接收上行链路 C 波段和 Ku 波段信号并输出 C 波段/Ku 波段下行链路信号，该通用替换卫星包括：

(a) Ku 波段处理装置，用于(i)接收 Ku 波段上行链路信号，该信号位于三个 250MHz 上行链路波段的信道中，这三个波段为，13.75-14.00GHz,14.00-14.25GHz 和 14.25-14.50GHz，每一上行链路波段有多个上行链路 Ku 波段信道，（ii）放大信号，（iii）对它们的频率进行下变频，和（iv）将任何已放大，降频的 Ku 波段信号作为 6 个 250MHz 波段的信道里的 Ku 波段下行链路信号输出，这 6 个 250MHz 波段位于 10.95-11.20GHz,11.45-11.70GHz,11.70-12.20GHz, 和 12.25-12.75GHz 下行链路 Ku 波段中，每一个下行链路波段有多个下行链路 Ku 波段信道；

(b) 两个以上的 Ku 波段下行链路天线，每一个天线能够输出包括 Ku 波段下行链路信号的下行链路波束，每一下行链路波束可单独地传送到地球上不同的地点；

(c) 用于将 Ku 波段下行链路信号传送到两个以上的 Ku 波段下行链路天线中的任一个天线的装置；

(d) C 波段处理装置，用于(i)接收位于两个上行链路波段信道中的 C 波段上行链路信号，这两个上行链路波段约在 5.925 到 6.425GHz 和 6.425 到 6.725GHz 之间，每一上行链路波段有多个上行链路 C 波段信道，（ii）放大信号，（iii）对它们的频率进行下变频，和（iv）将任何已放大，降频的 C 波段信号作为 3.70-4.20GHz 和 3.40-3.70GHz 下行链路 C 波段的信道内的 C 波段下行链路信号输出，每一个下行链路 C 波段有多个下行链路 C 波段信道；

(e) 两个以上的 C 波段下行链路天线，每一个天线能够输出包括下行链路 C 波段信号的下行链路波束，每一下行链路波束可单独地传送到地球上不同的地点；

(f) 用于将 C 波段下行链路信号传送到两个以上的 C 波段下行链路天线中的任一个天线的装置；

(g) 推力分系统，被设计来允许在其设计寿命期中卫星做至少 3 次快速移动,每一次快速移动达到每天至少 3 度；

(h) 电源分系统为卫星工作提供电源；

(i) 遥测指令分系统,使卫星能够监测自身的状况和与外部控制系统通信，该分系统包括至少能以两种不同频率发送信号的遥测子系统和至少可以两种不同频率接收信号的指令子系统；

(j) 姿态和轨道控制分系统，该系统用于帮助将卫星相对地球定向；

(k) 温度控制分系统，该系统帮助维持卫星在一个合适的工作温度范围内；和

(l) 重新配置卫星的装置，该装置包括(i) 远程调整 Ku 波段处理装置，将至少 2 路、但少于每一上行链路 Ku 波段中的所有信号的包传送到每一下行链路 Ku 波段中的装置，（ii）用于远程调整来自至少一个 Ku 波段下行链路天线中的下行链路波束，以将下行链路波束传向地面上的不同位置的装置，（iii）用于远程调整来自至少一个 C 波段下行链路天线的下行链路波束，以将该波束传向地球上的不同位置的装置，（iv）用于远程改变来自至少一个下行链路天线的下行链路波束的覆盖区域的装置，（v）用于远程改变来自至少一个下行链路

天线的极性的装置。

本发明的另一方面涉及一种通用替换通信卫星，这种通信卫星被设计为在对地静止轨道上绕地球运行，它可以被外部控制系统控制，能够重新配置，能够进行已有的对地静止的 C 波段和 Ku 波段通信卫星的大部分通信功能，也因此这种卫星能作为替换卫星。通用替换卫星设计为接收上行链路 C 波段和 Ku 波段信号并输出 C 波段/Ku 波段下行链路信号，通用替换通信卫星包括：

（a） Ku 波段处理装置，用于(i) 在三个 250MHz 上行链路波段的信道中接收 Ku 波段上行链路信号，这三个波段为，13.75-14.00GHz，14.00-14.25GHz 和 14.25-14.50GHz，每一上行链路波段有多个上行链路波段信道，（ii）放大信号，（iii）对它们的频率进行下变频，和（iv）输出任何已放大并降频的 Ku 波段信号作为 6 个 250MHz 波段信道里的 Ku 波段下行链路信号，这 6 个 250MHz 波段位于 10.95-11.20GHz，11.45-11.70GHz，11.70-12.20GHz 和 12.25-12.75GHz 下行链路 Ku 波段中，每一个下行链路波段有多个下行链路 Ku 波段信道；

（b） 两个以上的 Ku 波段下行链路天线，每一个天线能够输出包括 Ku 波段下行链路信号的下行链路波束，每一下行链路波束可单独地传送到地球上不同的地点；

（c） 用于将 Ku 波段下行链路信号传送到两个以上的 Ku 波段下行链路天线中的任一个天线的装置；

（d） C 波段处理装置，用于(i)在两个上行链路波段信道中接收上行链路信号，这两个上行链路波段约在 5.925 到 6.425GHz 和 6.425 到 6.725GHz 之间，每一上行链路波段有多个上行链路波段信道，（ii）放大信号，（iii）对它们的频率进行下变频，和（iv）输出任何已放大并降频的 C 波段信号，作为 3.70-4.20GHz 和 3.40-3.70GHz 下行链路 C 波段信道内的 C 波段下行链路信号，每一个下行链路 C 波段有多个下行链路 C 波段信道；

（e） 两个以上的 C 波段下行链路天线，每一个天线能够输出

包括 C 波段下行链路信号的下行链路波束，每一下行链路波束可单独地传送到地球上不同的地点；

（f） 用于将 C 波段下行链路信号传送到两个以上的 C 波段下行链路天线中的任一个天线的装置；

（g） 推力分系统，被设计来允许卫星在其设计寿命期中做至少 3 次快速移动；

（h） 电源分系统，为卫星工作提供电源；

（i） 遥测指令分系统,使卫星能够监测自身的状况和与外部控制系统通信；

（j） 姿态和轨道控制分系统，该系统用于帮助将卫星相对地球定向；

（k） 温度控制分系统，该系统帮助将卫星维持在一个合适的工作温度范围内；和

（l） 重新配置卫星的装置。

另一方面，本发明涉及一种通用替换通信卫星，这种通信卫星被设计为在对地静止轨道上绕地球运行，它可以被外部控制系统控制，能够重新配置，能够进行已有的对地静止的 C 波段和 Ku 波段通信卫星的大部分通信功能，从而这种卫星才能作为替换卫星。该通用替换卫星设计用于接收上行链路 C 波段和 Ku 波段信号，并输出 C 波段和 Ku 波段下行链路信号，该通用替换通信卫星包括：

（a） Ku 波段处理装置，用于(i)在三个上行链路波段的信道中接收 ku 波段上行链路信号，每一上行链路波段有多个上行链路 Ku 波段信道，（ii）放大信号，（iii）对它们的频率进行下变频，和（iv）输出任何已放大并降频的 Ku 波段信号，作为至少 4 个 Ku 波段下行链路波段内任一波段的信道内的 Ku 波段下行链路信号，每一个下行链路波段有多个下行链路 Ku 波段信道；

（b） 两个以上的 Ku 波段下行链路天线，每一个天线能够输出包括 Ku 波段下行链路信号的下行链路波束，每一下行链路波束可单独地传送到地球上不同的地点；

（c） 用于将 Ku 波段下行链路信号传送到两个以上的 Ku 波段下行链路天线中的任一个天线的装置；

（d） C 波段处理装置，用于(i)在至少一个上行链路波段的信道中接收 C 波段上行链路信号，每一上行链路波段有多个上行链路 C 波段信道，（ii）放大信号，（iii）对它们的频率进行下变频，和（iv）输出任何已放大并降频的 C 波段信号，作为至少一个下行链路 C 波段信道内的 C 波段下行链路信号，每一个下行链路波段有多个下行链路 C 波段信道；

（e） 一个以上的 C 波段下行链路天线，每一个天线能够输出包括下行链路 C 波段信号的下行链路波束，每一下行链路波束可单独地传送到地球上不同的地点；

（f） 用于将 C 波段下行链路信号传送到一个以上的 C 波段下行链路天线中的任一个天线的装置；

（g） 推力分系统，被设计来允许在卫星的设计寿命期中做至少两次快速移动；

（h） 电源分系统，为卫星工作提供电源；

（i） 遥测指令分系统,使卫星能够监测自身的状况和与外部控制系统通信，该分系统包括至少能以两种不同频率发送信号的遥测子系统和至少可以两种不同频率接收信号的指令子系统；

（j） 姿态和轨道控制分系统，用于帮助将卫星相对地球定向；

（k） 温度控制分系统，帮助将卫星维持在一个合适的工作温度范围内；和

（l） 重新配置卫星的装置，该装置包括（i）用于远程调整 Ku 波段处理装置，将至少 2 路但少于每一上行链路 Ku 波段中的所有信号的包传送到任一下行链路 Ku 波段的装置，（ii）用于远程调整来自至少一个 Ku 波段下行链路天线中的一个的下行链路波束，以将该波束传向地面上不同位置的装置，（iii）用于远程调整来自至少一个以上的 C 波段下行链路天线中的一个天线的下行链路波束，以将该波束传向地球上的不同位置的装置，（iv）用于远程改变来自至少一个下行链路天线的下行链路波束的覆盖区域的装置，和（v）远程改变来

自至少一个下行链路天线的极性的装置。

在一些优选实施例中，C 波段处理装置能够输出已放大并降频的C波段信号，作为 3.70-4.20Ghz 或 3.40-3.70GHz 下行链路 C 波段的信道中的 C 波段下行链路信号；Ku 波段处理装置能够将一个 Ku 波段下行链路中的部分而不是全部的信号传送到 6 个 250MHz 的下行链路 ku 波段的任何一个，也能够将这一 Ku 下行链路波段中的其它信号传送到这 6 个下行链路 Ku 波段中相同或不同的一个波段；用于远程调整 Ku 波段处理装置以引导信号装置，包括：远程调节 ku 波段处理装置以改变信号下变频的频率的装置；信号下变频装置包括，例如频率合成器或固定振荡器；卫星有至少两个上行链路 C 波段天线，至少有两个上行链路 Ku 波段天线，所有上行链路天线独自地指向地球上的不同位置；上行链路天线也可作为下行链路天线工作；卫星设计为：在设计寿命期的初期，Ku 波段处理装置能处理至少 32 路上行链路 Ku 波段信道中的信号，且 C 波段处理装置能处理至少 32 路上行链路 C 波段信道中的信号；卫星设计为，在其设计寿命末期，Ku 波段处理装置能处理至少 24 路上行链路 Ku 波段信道中的信号，且 C 波段处理装置能处理至少 24 路上行链路 C 波段信道中的信号；该卫星具有远程改变至少一个下行链路天线极性的装置，这些装置包括有将线性极性远程改变为圆形极性或相反方式改变，和/或将垂直极性远程改变为水平极性或相反方式改变，和/或将顺时针极性远程改变为逆时针极性或相反方式改变的装置；重配置卫星的装置包括用于远程调整 Ku 波段处理装置，将少于每个上行链路 ku 波段中所有信号的波束引入任一下行链路 ku 波段的装置，例如 2 路，3 路，6 路或其它路数的信号；该卫星具有远程改变下行链路波束的覆盖区域的装置，该下行链路波束来自至少一个 Ku 波段下行链路天线和至少一个 C 波段下行链路天线；来自至少下行链路天线中之一的下行链路波束可以独立地指向地球上不同的位置；该卫星设计为在其设计寿命期内能做至少 3 次快速移动，每次移动至少要达到每天 5 度；遥测指令分系统包括一个至少能以 2 种（优选的是 4 种）不同频率发送信号的遥测子系统和一个至

少能以 2 种（优选的是 4 种）不同频率接收信号的指令子系统；一些（优选是所有的）Ku 波段信道具有标准带宽，标称的标准带宽为 36MHz（包括一些 35MHz 宽度的信道）；替换卫星还包括 BSS 波段处理装置，该装置包括进行以下操作的装置：(i)在 17.3GHz 到 18.1GHz 频率范围上接收 BSS 上行链路信号，（ii）放大 BSS 信号，（iii）对它们的频率进行下变频，和（iv）输出已放大并降频的 BSS 波段信号，作为给下行链路 ku 波段信号提供的波段信道中的 BSS 下行链路信号。

另一方面，本发明涉及一种代替对地静止通信卫星处理 C 波段和 Ku 波段信号的方法，该方法包括：提供本发明的通用替换通信卫星，将替换卫星置于一适合的对地静止位置，重新配置替换卫星以使该卫星实现被替换卫星的通信功能。优选的，该方法还包括将替换卫星置于一储备轨道，典型地，此轨道的平面相对于对地静止位置的轨道平面倾斜，利用组合漂移和倾角操纵器将替换卫星从储存轨道移动到合适的对地静止位置。

对于本领域技术人员，本发明的其它特征和优点将是显而易见的。

发明的具体实施方式

本发明的替换卫星是一种切实可行的卫星（在技术上，经济上和其它方面），该卫星能够仿效绝大多数已有的和将来的工作于固定卫星业务波段（FSS）的对地静止通信卫星的通信性能，这种备用卫星正如国际电信联盟（ITU）所定义（即是 C 波段/Ku 波段通信卫星）。通常，本发明卫星的设计不是关键的，任何具有本发明所要求的特征和能够实现本发明的好处的设计都可使用。

本发明的卫星设计寿命应当至少为 9 年，合适地可达 10 年，更合适地至少 11 年，最合适地至少为 12 年，较好地至少为 13 年，更好地至少为 14 年，最好地至少为 15 年。正如下面所讨论的，以 14

年寿命期当作设计能够以至少每天 5 度（地球赤道经度）做 4 次快速移动的本发明的卫星的设计寿命目标是合适的。

本发明的卫星的重要特征包括它的可重配置性（例如，备用卫星具有可重配置的通信载荷，灵活的异频雷达发射机设计和灵活的遥测指令设计）；从地球上不同的位置拾取信号，将信号放大后将该信号重传送到地球上不同位置，同时修正一个以上的下行链路覆盖区域的能力；从储存位置迅速地移动到所需位置（例如，使备用卫星可恢复失效的或正失效的卫星的远程通信功能的位置）的能力。

概括地说，可认为通信卫星有 7 个分系统：结构系统，电源系统，温度控制系统，姿态轨道控制系统，推力系统，遥测指令系统和通信系统。

结构分系统包括卫星的构架，在它上面和它内部安装有卫星的其余部件。本发明的卫星结构系统的设计不是关键的，一旦本技术领域的熟练技术人员了解在此公开的发明的特征，他们将熟知结构系统的设计。概而言之，本发明的卫星结构分系统实质上与传统的 C 波段/Ku 波段通信卫星的结构相同。大的电线要优先考虑，因此，可以使用例如象 Lockheed Martin A2100，Loral FS1300，或 Hughes HS60/HP 或 HS702 的电线。对于特定的实施例，可以使用 Loral FS1300。

电源分系统包括太阳能电池板，它产生电能且被置于卫星外部；储存电能（例如，太阳能电池板产生的且在产生时未被使用的电能）的电池，将电传送到需要电能的各种卫星部件的网络。当太阳能电池板不能提供所需的全部电力时，电将被从电池中取出使用。本发明卫星的电源分系统的设计并不是关键的，一旦本技术领域的熟练技术人员了解在此公开的发明的特征，他们将熟知电源分系统的设计。

概而言之，本发明的卫星的电源分系统能提供的功率至少达 8 千

瓦，最好至少达 10 千瓦。在卫星设计寿命末期，电源分系统应能提供充足的电源容量以供至少 24 路 C 波段信道（转发器）和至少 24 路 Ku 波段的信道（转发器）工作。优选地，在卫星设计的初期，电源分系统提供充足的电源容量以供至少 30 路（较好地，至少 32 路，更适合地，至少 36 路）C 波段的信道和至少 30 路（较好地，至少 32 路，更适合地，至少 36 路）Ku 波段的信道。本发明的卫星中，合适的是，C 波段信道每一信道具有大约 35-40 瓦的下行链路功率，Ku 波段信道每一信道具有大约 100-150 瓦的下行链路功率。

温度控制分系统帮助维持卫星工作部件在合适的工作温度范围内以使卫星能够良好工作。因此，作为卫星工作付产品而产生的热量（如通信子系统工作产生的热量）将排出卫星之外。卫星的温度控制系统的设计并不是关键的，一旦本技术领域的熟练技术人员了解在此公开的发明的特征，他们将熟知温度控制系统的设计。本发明的卫星可使用一种热循环传输介质（基本类似于热泵）将热能从高温处转移到低温处。该卫星也可以使用热辐射表面。总体来说，本发明的卫星的温度控制分系统与传统卫星的温度控制分系统相似，其主要的区别如下文所述。

传统的 C 波段/Ku 波段通信卫星中，通信子系统基本上工作于卫星的整个寿命期，于是一直产生大量的热量付产品，因此需要设计温度控制系统；然而，本发明的卫星中，通信子系统通常仅当它被作为以失效或正失效的卫星的备用卫星或备份卫星使用时才工作（从而产生热付产品）。因此，本发明的卫星提供了加热器，当卫星通信系统没有使用时工作，从而产生与通信子系统工作时产生的热量大致相同的热量时。这种设计的结果是，使温度控制系统的热负载保持大致恒定，从而简化了温度控制系统的设计。

姿态轨道控制分系统帮助将卫星指向地球从而相对地球适当定向。卫星的姿态轨道控制分系统的设计并不是关键的，一旦本技术领

域的熟练技术人员了解在此公开的发明的特征，他们将熟知姿态轨道控制分系统的设计。概而言之，本发明的卫星的姿态轨道控制分系统基本上和任何一颗具有相同大小、重量、重量分布等的传统 FSS 卫星的姿态轨道控制分系统相同。

卫星推力分系统包括推进器和燃料供应。一般而言，各种力（例如，来自太阳和月亮的引力作用，大气阻力，地球的椭圆形状和太阳辐射）促使卫星从其位置移开。因此，卫星的推进器（发动机或马达）点火（通常以固定的间隔时间）进行位置保持以使卫星返回所期望的位置，也就是说，控制卫星的倾度、离心率和卫星的漂移。“倾角”为卫星实际轨道的平面（纬度的度数）相对于地球赤道平面（也就是北/南位置）的倾角。“离心率”为卫星轨道不圆率的度量，也就是说，是表示卫星和地球运动时它们之间的距离变化。“漂移”为卫星在西/东方向上的位置，例如，相对于地球的某一位置。

卫星的推力系统的设计并不是关键的，一旦本技术领域的熟练技术人员了解在此公开的发明的特征，他们将熟知推力系统的设计。能够以本发明的卫星作为替换卫星的对地静止的卫星典型地为三轴稳定卫星。这种卫星通常使用液体化学推进系统来实现位置保持，例如，用一组推进器来控制倾角，用第二组推进器来控制漂移和离心率。

概而言之，传统卫星不需要做 “快速移动”，因为，通常有充足的时间允许卫星在东/西方向移动或北/南方向进行位置保持（例如，通常允许有 30 到 60 天来做东/西向移动）。然而，本发明的卫星和传统卫星的一个主要不同点在于本发明的卫星必须能够做快速移动。由于本发明的卫星必须移动（通常从它的储备轨道地点）到要求用它备用或替换已失效或正失效的卫星的赤道位置上，它必须尽可能快地移动到该位置上以使减少卫星通信损坏时间（也就是不能够提供要求的通性能力的时间）。

典型地，本发明的卫星在储备时（也就是卫星处于它绕地球的储备轨道中），允许它在赤道平面内作南北向移动。正如本领域熟练的技术人员所知，如果将一颗卫星放置于对地静止赤道轨道上且没有位置保持，卫星将在赤道平面内缓慢地向南或北移动，最大达到赤道平面上方或下方的 8 度倾角，然后卫星向相反方向移动，直到卫星达到另一方向的大约最大的 8 度倾角。换句话说，如果卫星长时间储备而不进行位置保持，则本发明的卫星将在大约+8 度到-8 度倾角之间以几年的周期缓慢地振荡。

在目前可应用的规则下，例如，在联邦通信委员会（“FCC”）规则下，C 波段/Ku 波段对地静止卫星必须间距大约 2 经度（东经/西经）。对地静止卫星（位于大约 22,300 英里或 36,000 公里的高度）所位于的绕地球的赤道平面的圆周大约为 160，000 英里（大约 257，000 公里）。因此，2 经度的间距等于大约 800 英里（大约 1，300 公里）。由于在每一颗能用本发明的替换卫星作为备用的 C 波段/Ku 波段通信卫星的附近提供一颗本发明的替换卫星是不合算的，所以通常需要将本发明的替换卫星移动几千英里（或公里），使替换卫星到达合适的位置以取代已失效或正失效的卫星。因此，需要的卫星能够做快速移动。

“快速移动”指至少大约每天 2.5 度（地球赤道经度），合适的至少为每天 3 度，更合适的为至少每天 4 度，最合适的为至少每天 5 度，较好的为至少每天 6 度，更好的为至少每天 7 度，最好的为每天至少 8 度，甚至有时为至少每天 10 度。

本发明的卫星一般被设计为能够在其设计寿命中做至少两次快速移动，其移动速度合适的为至少每天 3 度（地球赤道经度），通常能够以至少每天 3 度做至少 3 次快速移动，合适的能以至少每天 4 度做 3 次快速移动，更合适的能以至少每天 5 度做至少 3 次快速移动，最合适的能以至少每天 6 度做至少 3 次快速移动，较好的能以至少每天

7 度做 3 次快速移动，更好的能以至少每天 8 度做至少 3 次快速移动，有时能以至少每天 10 度做至少 3 次快速移动，最好的能以至少每天 5 度做至少 4 次快速移动。因此，本发明的替换卫星将比以它作为备用卫星的典型的传统通信卫星携带更多的燃料，因为它需要有能力比传统的卫星做快得多的移动。

正如上文所提出，将 14 年作为目标设计寿命期来设计能够以至少每天 5 度（地球赤道经度）速度快速移动至少 4 次的本发明的卫星。如果卫星在其设计寿命期内的移动（重新定位）相当于少于前面提及的次数（换句话说，少于以至少每天 5 度的 4 次快速移动的相当次数），卫星的寿命将比 14 年的设计寿命长（假设没有别的因素限制）。因为本发明的卫星携带的燃料量成为限制卫星寿命的因素，在合适的时候采用各种技术来减少燃料的消耗，例如，采用一种“组合漂移倾角操作”（如下文描述）使卫星从其储存（或停留）位置移到适合替换（备用）已失效或正失效的卫星的位置，使用缓慢漂移来使卫星从替换（备用）位置回归到储存（或停留）地点（位置）。

任何能够使卫星做所要求的多次快速移动的推力系统都可采用，例如，流体（例如液体）或固体或等离子体推力系统，例如，基于氧化剂的推力系统（例如，使用诸如一甲基肼的肼燃料系统）。没有足够的能量或不适于用于卫星做所要求次数的快速移动的推力装置，例如，氙离子推力系统（“XIPS”），可以用于进行北/南位置保持。

本发明的替换卫星当将它从储存地点移动到适合于备份或备用已失效或正失效的卫星的位置（“合适的位置”）时可做组合的漂移倾角操作，因此，减少了所需的燃料量，否则的话将需要这些燃料使卫星移动。采用“漂移倾角操作”意指这样一种操作，将卫星定向且同时点燃卫星推进器，以使卫星从储存地点到合适位置的移动过程中在一些地点同时发生东/西（漂移）和北/南（倾角）运动。（如果卫星正在第一个合适的位置被使用以替换第一颗已失效或正失效的卫星，

然后移动到第二合适位置以替换第二个失效或正失效卫星，则第一个合适的位置将被当作储存地点，该替换卫星从该位置移动到第二个合适的位置。）

遥测指令分系统包括两个子系统，遥测子系统和指令子系统。遥测子系统监视卫星的健康并往外传送信息（例如，传送到地面控制站），指令子系统从卫星外部（例如，从地面控制站）接受指令。卫星的遥测指令子系统的设计并不是关键的，一旦本技术领域的熟练技术人员了解在此公开的发明的特征，他们将熟知遥测指令子系统的设计。概而言之，本发明的卫星的子系统基本上和传统的 C 波段 Ku 波段通信卫星相同，下文所说的除外。

用本发明的卫星作备用的或用本发明的卫星替换的典型的传统 C 波段/Ku 波段通信卫星如此设计，遥测子系统只用一个或两个频率来发送信号，指令子系统只用一个或两个频率来接受信号。本发明的卫星的一个特点是设计为至少有 2 种不同的频率（合适的至少 3 种，较好的至少 4 种，最好的至少 5 种频率）可供使用，且被遥测子系统用于发送，至少有 2 种不同的频率（合适的至少 3 种，较好的至少 4 种，最好的至少 5 种不同频率）可供使用，且被指令子系统用于接收。本发明的卫星中，普遍地，提供了 4 种不同的频率供遥测子系统使用，提供了 4 种不同频率供指令子系统使用。任何为本技术领域熟练的技术人员所了解的技术方案都可用于改变每一个子系统的频率，例如，频率合成器和固定频率发生器。

有如此之多的频率供每一子系统使用是很重要的，因为这允许用于一个指定的任何一个 ITU 区域的频率可从本发明的卫星提供的频率中选出，以避免发生干扰，例如，避免和靠近替换位置的正运转的卫星发生干扰。合适的是，一个以上的遥测指令天线的极性可以转换（例如，从线性极性转为圆性极性或圆性极性转为线性极性，和/或从垂直极性转为水平极性或水平极性转为垂直极性，和/或从顺时针极性转为

逆时针极性或逆时针极性转为顺时针极性）。这进一步增强了本发明的卫星避免发生干扰的能力，例如，避免和相邻卫星发生干扰。同样合适的是，可以调整一个以上的遥测指令天线以改善发送和/或接受信号的质量。因此，例如，通过移动天线本身和/或使用诸如相阵列技术的装置来调整它的波束，将遥测天线的波束定好位以使波束到达地球的不同地点。同样地，可将指令子系统的接收天线定好位以使它指向地球的不同地点。

基于以下原因，优选地，使用全向（全向的）天线为主天线用于遥测指令子系统。通常，一旦位于其轨道并处于工作，传统 C 波段/Ku 波段通信卫星将通过 C 波段或 Ku 波段本身接受和传输遥测指令信号，那些波段通常使用高增益天线；然而，本发明卫星能作为许多不同设计的卫星的备份卫星，而且那些不同设计的卫星可能位于整个对地静止的赤道平面内的许多不同的地点，用于本发明的替换卫星中的高增益天线可能无法和用于被替换卫星的地面遥测指令站联系上。因此，在本发明的替换卫星上，遥测指令子系统优先使用全向天线而不是高增益天线。

通信子系统根据上行链路频率规划从地球接收信号，将信号进行放大，根据下行链路规划将信号重发送。本发明的卫星的通信子系统的设计并不是关键的，一旦本技术领域的熟练技术人员了解在此公开的发明的特征，他们将熟知通信子系统的设计。

本发明卫星的通信子系统设计为处理 C 波段和 Ku 波段信号。C 波段具有 6GHz 频宽的上行链路频率和 4GHz 频宽的下行链路频率。Ku 波段具有 14GHz 频宽的上行链路频率和 12GHz 频宽的下行链路频率。

概而言之，通信子系统包括：（a）上行链路天线，它在预先选定的一个以上的波段上接收上行链路通信信号，每个波段有不止一个

信道，（b）一个以上的滤波器，允许预先选定的波段中的信号通过，同时滤掉任何噪声或者预先选定波段之外的频率中的信号，（c）一个以上的放大器，增加所要求的信号的强度（例如，在信号经过一个以上的滤波器后，增强信号的强度），（d）一个下变频器，将上行链路频率降到下行链路频率，（e）将上行链路信号（该信号被一个以上的 C 波段天线和一个以上的 Ku 波段天线接收）传到合适的一个以上的下行链路 C 波段天线和一个以上的 Ku 波段天线的装置，和（f）一个以上的 C 波段天线和一个以上的 Ku 波段天线。将信号传到合适的天线的的装置可包括下变频器（它本身可能包括交换器，固定频率发生器，频率合成器等，以使各种信号能被转换到所要求的频率且那些频率可以更改），交换器，多路输入器（IMUXs），多路输出器（output MUXs）等。

ITU 分配的原始 C 波段上行链路范围为 5.925GHz 到 6.425GHz（500MHz 的带宽），相应的下行链路范围为 3.7GHz 到 4.2GHz（也是 500MHz 的带宽）。ITU 后来给出了第二个波段，也就是分配 6.425 到 6.725GHz 给上行链路（300MHz 的带宽），分配 3.4GHz 到 3.7GHz 给相应的下行链路（也是 300MHz 的带宽）。最近，又为 C 波段上行链路信号提供了第三个波段，也就是 5.85GHZ 到 5.925GHz（75MHz 的带宽），但没有给下行链路分配附加的波段。到目前为止，这第三个 75MHz 下行链路 C 波段很少或没有被使用过。因此，C 波段上行链路信号可位于所分配的三个上行链路波段中的任何一个，三个波段是连续的且覆盖 5.85GHz 到 6.725GHz（总计 875MHz 带宽），C 波段下行链路信号可位于所分配的两个下行链路中的任何一个，这两个波段是连续的且覆盖 3.4GHz 到 4.2GHz（总计 800MHz 带宽）。

原则上，由于 ITU 条款规定了能被地球上三个不同 ITU 区域的每一个 C 波段/Ku 波段通信卫星使用的频率，典型地，处理 C 波段通信的卫星将只工作于上行链路的 500MHz（位于 875MHz 内）和下行链路的 500MHz（位于 800MHz 内）。因此，通用替换卫星必须至少

能处理两个早期的从 5.925GHz 到 6.725GHz 的上行链路 C 波段的 800MHz 的带宽（最好可处理 875MHz 的整个上行链路范围内，包括 5.85GHz 到 5.925GHz 之间的 75MHz 带宽），它也必须能够处理两个下行链路 C 波段的整个 800MHz 的带宽。

概而言之，在 500MHz C 波段内有 24 路信道，其中 12 路已有一种极性（如果使用线性极性则可为垂直极性或水平极性，如果使用圆性极性可为顺时针或逆时针极性）。例如假设使用线性极性，12 路垂直极性的每一信道将为标称的 36MHz 宽度，在信道间有保护带，在 500MHz 范围内的顶部有一保护或缓冲区波段，在 500MHz 范围内的底部有一保护或缓冲区波段。这解释了人们用 500MHz 除以 12 计算后得出的每信道大约 41.7MHz 和所提供的标称的每信道 36MHz 之间的差别。对于 1 两个垂直极性的信道而言情况相同。正如本领域熟练的技术人员所理解的，两组 12 信道，每一信道都为标称的 36MHz 宽度，由于两组信道具有不同的极性，所以可以共存于同一 500MHz 带宽内。如果使用圆性极性，500MHz 带宽的 24 信道可以用同样的分析方法。

对于传统的卫星，24 路上行链路信道可全被地球上大体上相同地点的一个以上的天线发射，或者 24 路信道可能由位于几个不同地点中的每一个地点的一个以上的天线提供信号。因此，设计用于预定位置的传统卫星将被设计为捕获来自所有为它提供给信号的发射天线的 24 路信道，这就要求两个或更多的上行链路天线。由于传统的卫星被置于预先指定的位置，天线的几何尺寸在设计前是知道的（也就是，地球上的一个以上的发射天线和卫星的一个以上的接收天线之间的空间关系是已知的），因此，在卫星上和相对卫星星体的每一个卫星上行链路天线的位置和方位可以预先确定并安装。

另一方面，为使本发明的替换卫星更大程度地仿效 FSS 卫星，它的一些（最好为所有）上行链路天线必须是可独立操纵的以使天线能

很好地捕获地球上天线发射的信号，这些信号是传送给将被本发明的卫星替换的已失效或正失效的卫星。替换卫星将使用至少两个上行链路 C 波段天线，可能的话至少为 3 个天线，有时候至少为 4 个天线。至少有一个（最好为所有）的 C 波段上行链路 C 波段天线的极性可以更改以适应被替换的已失效或正失效的卫星的预先设定的上行链路频率规划。

相同的考虑应用于下行链路 C 波段和下行链路天线。因此，在传统的 FSS 卫星中 C 波段下行链路为 500MHz 宽度，有 24 路信道（每一信道为标称的 36MHz 宽度），以 2 组垂直和水平信号极化或以 2 组顺时针和逆时针信号极化，下行链路信号将对准地球上的一个以上的地点的一个以上的接收天线。此外，由于在设计传统的 FSS 卫星前几何尺寸是知道的（也就是说，卫星上的每一个下行链路天线和地球上预期的接收区域或地球上的天线间的距离和方向），下行链路天线将固定于这个卫星上的位置和方位。

本发明的替换卫星使用至少两个下行链路 C 波段天线，合适地至少 3 个，较好地为至少 4 个，有些情况下为 5 个天线。至少一个（合适地为两个，3 个，4 个或多个）的 C 波段下行链路天线的极性可以更改以适应将被替换的已失效或正失效的卫星的预定的下行链路规划。至少一些，最好大多数的天线有足够的增益和宽阔的覆盖范围。用于 C 波段下行链路天线的最小 EIRP（有效全向辐射功率）最好是 36dbw（瓦特参考点的分贝值）。

至少有一个（合适的为两个，3 个，4 个或更多）的 C 波段下行链路天线必须有可独立定向的波束以使它们能将足够强的信号发送给地球上正从将被本发明的卫星所替换的已失效或正失效的卫星接收信号的所有天线。可以用任何一种合适的方式引导从一天线发出的波束，例如，操纵天线本身，使用多波束天线，使用相阵列天线或使用其它任何类型的可重配置的天线（参见，例如 US 4,965,587）。

C 波段上行链路信号可能仅从几个天线（也许只是地球上的一个发射天线）发出，与之不同的是，可能必须将一个以上的下行链路信号传送到大片区域的多个天线，例如，发送到遍及整个美国大陆的所有电视光缆公司的接收天线，这些公司携带一些特别的信号以重新发布给它们的客户（例如，来自一全国发行的电影或体育节目的提供商的信号，该信号上传到卫星然后从卫星下传到遍及美国的光缆公司，每一个光缆公司重新发布信号给它自己的客户）。也可能是必须将特别的下行链路波束发送到一很受限制的地理区域。因此，至少一个（合适的为两个，3 个，4 个或更多）的 C 波段下行链路的覆盖区域能够更改将是合适的。可以使用任何合适的方式来改变天线的下行链路波束的覆盖区域，例如，通过操纵（移动或重定向）天线和/或通过天线波束的形状（例如，使用相阵列天线，可重配置的天线或其它任何合适的方法）。

整个上行链路 Ku 波段占用 13.75GHz 到 14.5GHz，它被认为拥有 3 个上行链路波段，它的每一个波段为 250MHz 宽度且为连续的，换句话说，一个波段从 13.75GHz 到 14.00GHz，第二个波段为 14.00GHz 到 14.25GHz，第三个波段为 14.25GHz 到 14.50GHz。相比之下，下行链路波段有几个，但只有一些是连续的。第一个标准的下行链路波段位于 10.95GHz 到 11.20GHz（250MHz 带宽），第二个标准的下行链路波段位于 11.45GHz 到 11.70GHz（250MHz 带宽），第三个标准的下行链路波段位于 11.70GHz 到 12.20GHz（500MHz 带宽），第四个标准的下行链路波段位于 12.20GHz 到 12.75GHz（550MHz 带宽）。第四个标准的波段本身可认为包括两个标准的波段，一个从 12.2 到 12.5GHz，为 300MHz 波段，另一个从 12.5 到 12.75GHz，为 250MHz 波段，总计 5 个波段。

正如上文所述，本发明的卫星在技术上、经济上或其它方面都是切实可行的。通过仔细地确定与包括所有需用来完全仿效所有已有的

和将来有的 FSS 卫星的特征相对的可行性的特征，可行性已得到实现。因此，尽管从 12.20 到 12.25GHz 的 50MHz 带宽是由 ITU 分配用于下行链路 Ku 波段信号的一部分频谱，在发明的一些优选实施例中，没有使用这个 50MHz。因此，在那些实施例中，第四个波段是从 12.25GHz 到 12.75GHz（500MHz 波段）。在一些优选实施例中没有使用从 12.20 到 12.25GHz 的 50MHz 的带宽，从而简化了本发明的卫星的设计，因为在那些实施例中，使用的所有的上行链路和下行链路 Ku 波段频谱能方便地划分成 250MHz 的块（3 个上行链路 250MHz 波段和 6 个 250MHz 下行链路波段）。在那些也利用从 12.20 到 12.25GHz 的 50MHz 带宽的实施例中则不在此列（因为所使用的从 12.20 到 12.75GHz 的第四波段是 550MHz 宽度）。

因此，从一个角度看，在那些没有使用 12.20 到 12.25GHz 的 50MHz 带宽的实施例中，名义上有 4 个下行链路 Ku 波段，其中两个波段各有 250MHz 的带宽，另两个波段各有 500MHz 的带宽（也就是 10.95-11.20，11.45-11.70，11.7-12.2，12.25-12.75GHz）。从另一角度看，在那些优选实施例中，有 6 个下行链路 Ku 波段，每一个波段为 250MHz 带宽。不论有多少个 Ku 波段，总计有 1550MHz（1.55GHz）非连续的带宽，该带宽由 ITU 为 Ku 波段下行链路信号分配，位于 10.95GHz 到 12.75GHz 的范围内；然而，在本发明的一些优选实施例中，只有 1500MHz（1.5GHz）被使用。

可以理解，在权利要求书中，从 12.25 到 12.75GHz 的波段，被认为包括两个各为 250MHz 的波段，位于 12.20 到 12.75GHz 的波段中。因此，权利要求书中的“输出任何已放大、降频的 Ku 波段信号，作为 6 个 250MHz 波段中信道里的 Ku 波段下行链路信号，这 6 个 250MHz 波段位于 10.95-11.20GHz,11.45-11.70GHz,11.70-12.20GHz 和 12.25-12.75GHz 下行链路 Ku 波段，每一个下行链路 Ku 波段有多个下行链路 Ku 波段信道”，如果仅仅通过使用另外的 12.20 到 12.25GHz 之间的 50Mhz，是不能避开这项权利要求的保护范围的。

原则上，由于 ITU 规则规定了能被 C 波段/Ku 波段通信卫星使用的频率，该频率用于地球的三个不同的 ITU 区域，典型地，处理 Ku 波段通信的卫星将只在上行链路的 500MHz（分配的 750MHz）波段和下行链路的 500MHz（分配的 1550MHz）波段工作。因此，通用替换卫星必须能够处理上行链路 Ku 波段的所有 750MHz 带宽（本发明就是这样做），也必须能够处理大多数，即使不是全部的已分配的下行链路 Ku 波段的 1550MHz 带宽（正如所述，在本发明的一些优选实施例中，可用的 1550MHz 带宽中只有 1500MHz 被使用）。

概而言之，在本发明的卫星中，典型地，对于两种极性（也就是垂直和水平，或顺时针和逆时针）总计有 72 路 Ku 波段下行链路信道，每一路 Ku 波段下行链路信道为标称的 36MHz 宽度（对每一种极性，用 1500MHz 除以 36 后约为 41.7MHz，41.7 和 36 间的差值是因为保护频带等的存在）。概而言之，在任何一颗传统的 FSS 卫星中使用的下行链路 Ku 波段不超过 750MHz。因此，优选的是，本发明的卫星设计为在寿命期开始以 36 路信道（两种极性的总和）工作（寿命期末期的设计目标是 24 路信道），尽管使用 36 路信道的哪一频率取决于被本发明的卫星替换的传统 FSS 卫星。

本发明的卫星的重要特征之一为该卫星能够在三个上行链路波段中的任一个上接收信号并将信号发送到四个标准下行链路 Ku 波段中的任一个（或将信号发送到五个下行链路 Ku 波段中的任一个，如果考虑有 5 个这样的信道）。优选的是，本发明的卫星能够在三个上行链路 Ku 波段上接收信号并将信号发送到 6 个 250MHz 带宽的下行链路 Ku 波段中的任一个。这一点帮助本发明的卫星仿效将被替换的已失效或正失效的 C 波段/Ku 波段通信卫星的通信性能。

象 C 波段一样，本发明的卫星的 Ku 波段信道每一个都为标称的 36MHz 宽度，最好使用极化（线性极性或圆性极性）。因此，500MHz

上行链路带宽总计有 24 路信道，其中 12 路信道为垂直极性，另 12 路信道为水平极性（或者 12 路信道为顺时针极性，另 12 路信道为逆时针极性）。先考虑 12 路垂直极性的信道，信道之间存在的保护带，位于 500MHz 范围顶部的保护或缓冲波段和位于 500MHz 范围底端的保护或缓冲波段说明了用 500MHz 除以 12 计算得出的大约每信道总计 41.7MHz 和标称的每信道 36MHz 之间的差别，标称的 36MHz 信道用于本发明的卫星中。对 12 路水平极性信道也是一样。正如本领域熟练技术人员所理解的，每一信道为标称的 36MHz 宽度的两组 12 路信道能够共存于同一 500MHz 带宽中，因为两组信道有不同的极性。对于 500MHz 波段的 24 路信道，如果采用圆极性，可用相同的分析方法。

Ku 波段没有一个标准的信道宽度，27，36，43，54，72 和 108MHz 的带宽都已被使用过或正被使用。因此，本发明卫星的另一个优选特征是对于大多数 Ku 波段（更优选的，所有的 Ku 波段）使用标准的带宽，更优选地，此带宽为标称的 36MHz。对于两个不连续的下行链路 Ku 波段（也就是从 10.95 到 11.2GHz 和从 11.45 到 11.70GHz）,优选的，信道为 35MHz 宽度，但是该宽度被认为是在“标称的 36MHz 宽度”和“一个标称的 36MHz 带宽”范围之内。对所有的上行链路和下行链路 Ku 波段使用标准的带宽（不论是标称的 36MHz 或其它一些值）使得，例如，处理其它带宽所需的滤波器和多路复用器可以省略，所以简化了设计且使本发明的卫星是切实可行的。

和 C 波段一样，对于传统的卫星，24 路上行链路信道可能被一个以上的位于地球上大体上同一地点的天线全部使用发射，或者信道可能被位于几个不同地点中的每一个地点的一个以上的天线供给信号。因此，为预定位置设计的传统卫星被设计来捕获来自所有将要供给它信号的发射天线的 24 路 Ku 波段信道（假设使用优选的 36MHz 标称带宽），这可能要求两个或更多上行链路天线。由于传统的卫星将位于预先指定的位置，在设计前几何关系是知道的（也就是说地球

上一个或更多个发射天线和卫星上一个以上的接收天线的空间关系是知道的），因此，在卫星上和指向卫星本体的每一个卫星上行链路天线的位置和方向可以事先确定和安装。

另一方面，为了使本发明的替换卫星能仿效 FSS 卫星的大部分功能，替换卫星的一些（优选地，为所有）的 Ku 波段上行链路天线必须能独立地操纵，以使它们能很好地捕获地球上发射天线发送的所有信号，这些信号正提供给本发明的替换卫星替换的已失效或正失效的卫星。替换卫星使用至少两个上行链路 Ku 波段天线，可能的话至少三个，有时候至少 4 个天线。至少一个（最好为全部）Ku 波段上行链路天线的极性可以更改以适应正被替换的已失效或正失效的卫星的预定的上行链路频率方案。

在传统的 FSS 卫星中，Ku 波段下行链路为 250、300 或 500MHz 宽度，其信道（最好每一信道为标称的 36MHz 宽度）要么以 2 组垂直和水平的方式极化要么以 2 组顺时针和逆时针方式极化，且下行链路信号将对准地球上一个以上的地点的一个以上的接收天线。此外，在设计传统的 FSS 卫星前几何关系是知道的（也就是说卫星上每一个下行链路 Ku 波段天线和地球上所要求的接收区域或天线的距离和方向是知道的），下行链路天线将固定在卫星上的位置和方位。

本发明的替换卫星将使用至少两个下行链路 Ku 波段天线，合适地使用至少 3 个，较好地使用至少 4 个，有时候使用至少 5 个。至少一个（最好 2、3、4 或更多）Ku 波段上行链路天线的极性可以更改以适应正被替换的已失效或正失效的卫星的预定的上行链路频率规划。至少有一些，最好是大多数的天线有足够的增益和宽阔的覆盖区域。优选地，Ku 波段下行链路天线的最小 EIRP（有效全向辐射功率）在覆盖区域的边缘为 48dbw 到 50dbw（位置）。Ku 波段上行链路天线应有不同的波束形状和增益水平，他们的设计为本领域熟练的技术人员所了解。

至少有一个（最好为两个，3 个，4 个或更多）的 Ku 波段下行链路天线必须有可独立传输的波束以使它们能将足够强的信号发送给地球上的所有天线，这些天线正从将被本发明的卫星所替换的已失效或正失效的卫星接收信号。正如 C 波段下行链路天线一样，可以使用任何合适的方式来导向从一个 Ku 波段天线发射出的波束，例如，使用本身可操纵的天线，使用多波束天线，使用相阵列天线或使用其它任何可重配置的天线（例如参见，US 4,965,587）。

上行链路 Ku 波段信号可能仅来自几个天线（也许只是一个地球上的发射天线），与该信号相比，一个以上的下行链路信号可能要发送到一大片区域中的多个天线，例如，发送到遍及整个美国大陆的所有电视光缆公司的接收天线，这些公司携带特别的信号以重新分送给它的客户。也可能需要把特定的下行链路波束发送到一很特别的地理区域。因此，最好至少一个（合适的为两个，3 个，4 个或更多）的 Ku 波段下行链路的覆盖区域是能够更改的。可以使用任何合适的方法来改变天线的下行链路波束的覆盖区域，例如，通过操纵（移动或重定向）天线和/或通过改变天线波束形状（例如，使用相阵列天线，可重配置的天线或其它任何合适的方法）。

例如，对于本发明卫星的一个可能的实施例，对于 Ku 波段，可能使用一个有很宽的覆盖区域的天线来为美国大陆，加拿大的下半部的部分地区和墨西哥的上部分地区提供至少 48dbw 的覆盖能力，还使用一个定点天线来为夏威夷提供至少 42dbw 的覆盖能力。关于本发明这个实施例的其它用途，被替换的卫星有五个 Ku 波段覆盖区域，一个以 42dbw 集中在印度，一个以 42dbw 集中在中国，一个以 50dbw 集中在南非，一个以 42dbw 集中在中东，一个以 42dbw 覆盖土耳其，北非和欧洲南部，但是替换卫星使用 4 个覆盖区域，一个以 50dbw 覆盖南非和其国家北部，一个以 48dbw 覆盖大半个印度和中国，一个以 48dbw 覆盖澳大利亚北部和位于澳大利亚和中国间的区域，一个以

48dbw 覆盖中东、土耳其、非洲北部和欧洲南部。本发明卫星的覆盖版图和功率水平与那些被替换的卫星是不一样的，但是非常接近，可以认为很好地模仿或仿效被替换卫星的通性能力。

对于 C 波段和 Ku 波段，本发明的另一个合乎要求的特征是，一些，最好是所有的替换卫星上的上行链路和下行链路天线在北/南和东/西方向都是可操纵的（或可移动的），从正常状态至少移动 2 度，合适地至少 3 度，更合适地至少 4 度，最合适地至少 5 度，较好地至少 6 度，更好地至少 7 度，在有些情况下从正常状态移动至少 8 度。在传统的 FSS 卫星中，相对正常位置，天线能移动的幅度很少超过南/北或东/西方向 1 度。本发明卫星的可操纵性有助于实现替换卫星的实用性，同时使替换卫星保持足够的灵活性以满足任何一颗 FSS 卫星的频率规划。下行链路天线的可操纵性可认为是用于导向从下行链路天线发射的波束（例如，相阵列或波束形成技术）的手段的附加。

正如我们所知，对于传统的 FSS 卫星，卫星接收的特定 C 波段或 Ku 波段信道上的信号可能必须和其它上行链路 C 波段或 Ku 波段信号一起重发射到特别的地理区域。因此，例如，第一个 Ku 波段上行链路信号可能必须导入服务于一地理区域的卫星的 Ku 波段下行链路天线，而第二个 Ku 波段上行链路信号可能必须导入到相同的下行链路天线。也有这样的情况，两个上行链路 Ku 波段信号位于具有上行链路频率的信道内，而它们要求不同的下变换“数量”以使能位于相同的天线。还有这样的情况，一波段中各种上行链路信号，甚至可能是地面上同一天线发射的信号，必须导入到两个或多个不同的下行链路天线。因此，传统的 FSS 卫星设计时需要知道上行链路频率规划（例如，发送上行链路信号的地球上每一天线的位置，每一信号有什么样的频率）和下行链路频率规划（例如，每一信号需要何种频率，该信号要发往何处）。这些使得相对容易地设计下变频器，输入多路复用器，输出多路复用器等。

本领域熟练的技术人员可以理解，各种现有的和已计划的 FSS 卫星有不同的上行链路和下行链路频率方案和很多不同的将各种上行链路信号重定向到合适的下行链路天线的方案。本发明的一个重要特征是能适应很宽范围的各种上行链路和下行链路规划，这些规划可在大多数（优选地绝大多数）现存的和已计划的 FSS 卫星中找到。

一颗完善的克隆替换卫星应包括所有的交换器、下变频装置、输入多路复用器、输出多路复用器等，需要这些来使替换卫星能完善地仿效在所有的 FSS 卫星的所有上行链路和下行链路频率规划。为达到完善的仿效，在克隆卫星中每一路上行链路信号将必须能够发送到任何一路下行链路信道，同时对正被发送的其它上行链路信号没有任何方面的影响；然而，这样一来使得设计变得不实用（例如，过于复杂），费用过高。

相比之下，本发明的卫星在技术上、经济上和其它方面都是切实可行的。正如前面所述，通过仔细地确定与包括所有需用来完全仿效的特征相对的需用于可行性的特征，其可行性已得到证实。因此，例如，卫星不是能够个别地和独立地将每一路上行链路信号变换到位于任一波段中的任一下行链路信道，而是至少一些，合适地为大多数，较好地是所有上行链路信号能成包地交换。那些包中每一包包括至少 2 路信号，合适地至少 3 路，更合适地至少 4 路，最合适地至少 6 路，较好地至少 7 路，更好地至少 8 路，最好地至少 9 路。在一些优选实施例中，一个包包括 12 路信号。显然，包中信号越多，处理装置（因此，也就是卫星）仿效 FSS 卫星的灵活性越少。因此，在一些优选实施例中，将 3 或 6 路信号打成一包。尽管不是一波段中的所有信号都需要打包或需要位于同样大小的包中，最好是将一波段中的所有信号打包且这些包具有相同的大小。因此，例如对于 Ku 波段，在卫星寿命期初期可能使用 36 路信道，在卫星寿命末期能够使用至少 24 路信道，最好，将所有信号打包，每一包可包括 3 或 6 路信号。正如本领域熟练的技术人员将理解的，每包中的信号数量越少，处理装置的粗

糙度越小。

可以使用任何具有这个功能或能实现本发明好处的装置将上行链路信号的频率下变频（向下频移）到合适的被使用下行链路信道的频率。这一设计并非关键的，一旦本领域熟练的技术人员理解在此公布的发明，他们将熟知它的设计。因此，需要实现信号下变频的灵活性的装置。这些装置包括频率合成器和振荡器（例如，固定频率振荡器）和交换设备。进一步的交换将已降频的信号导入到各种输入多路复用器，在那里 2 路或多路（例如，最好是 3 路或 6 路）被选择且被发送到放大器以提高他们的功率。然后，放大器的输出被送到输出多路复用器，在那里将单独的信号进行组合以将它发送到天线。正如本领域熟练技术人员所理解的，用于这些不同任务的具体的通路，设备和装置并不是关键的，可使用完成需要的功能或实现本发明的好处的任何装置。那些装置的设计并不是关键的，一但本领域熟练的技术人员理解在此公布的发明，他们将熟知它的设计。

正如本领域熟练的技术人员所理解的一样，将一特定的上行链路信号导入到一特定的下行链路天线通常涉及确定该信号的下行链路频率，然后使用替换卫星中提供的下变频装置将其变换成这个频率，该装置可能是，例如一频率合成器或固定频率振荡器，还有交换设备。第一路信号的频率改变（上行链路频率减去下行链路频率）为一确定的 Hz 数目。将另一路上行链路信号导入到相同的下行链路天线将涉及不同 Hz 数目的频率改变。使用替换卫星中的交换设备和输入和输出多路复用器，上述两路上行链路信号能得到处理，使他们可发送到相同的下行链路天线。换句话说，结果是那些信号将被一起打成包。

本发明的另一个重要特征是卫星能够远程进行重配置，也就是能将信号从地面指令站发送到卫星上，不仅使卫星从当前地点（该地点可以是位于储存轨道）移动，而且对卫星重配置来远程调整 Ku 波段下行链路波段处理装置，以将至少有 2 路信号但少于所有的位于每一

上行链路波段中的信号导入到下行链路 Ku 波段中的任一个波段，和/或远程调整来自至少一个 Ku 波段下行链路天线的下行链路波束，以将该波束传送到地球上的不同地点，和/或远程调整来自至少一个 C 波段下行链路天线的下行链路波束，以将该波束传送到地球上的不同地点，和/或远程改变来自至少一个 Ku 波段下行链路天线的下行链路波束的覆盖区域。能达到此重配置的装置，与所要求的附加改变一样（例如移动一个以上的上行链路天线），可以是任何一种能完成上述功能且能获得本发明的好处的的装置。那些装置的设计并不是关键的，一但本领域熟练的技术人员理解在此公布的发明，他们将熟知它的设计。

本发明的卫星可使用本领域熟练的技术人员所掌握的技术和手段将它发射且定位于储存轨道。因此，例如可使用诸如天顶号（Sea Launch），阿里亚娜号和质子号运载火箭。第一次放置于轨道的本发明的卫星典型地重达 4000 到 5000 公斤，更可能的重达 4300 到 4900 公斤。

典型地，初始储存轨道位于相对于赤道平面倾斜的一平面内。如上面所讨论的，本发明卫星的储存平面将在相对于赤道大约+8 度到大约-8 度之间来回摆动，除非有目的地移动卫星。因此，即使替换卫星开始时放置于相对于赤道倾斜的平面内用于储存，到替换卫星从储存轨道移动到工作位置时，储存轨道也许位于不同于它初始时被放置的位置。

最好使用由至少 2 颗（最好至少 5 颗）本发明替换卫星组成的星群。通常，他们储存于东/西方向的不同位置，尽管也许没有将他们均匀地分布在东/西方向。将替换卫星储存在靠近它要替换的传统卫星通常可以减少由于传统卫星失效出现的无效通信时间长度（因为替换卫星从储存位置移动到将要被替换的卫星的工作位置的距离短）。

本发明的卫星可以发射并放置于一轨道（储存）位置，该位置不需要单独的 ITU 许可。卫星的轨道允许相对于赤道平面上下移动（也就是，成为倾斜的）。当能以本发明的备份卫星作为备份的传统卫星失效到不可接受的程度后（它可以是部分失效，也可以是完全失效），将适当的指令从替换卫星外部（例如，从地面控制站）发送到替换卫星的指令子系统。结果是，替换卫星从其储存位置移动到它将要工作以替代正失效或已失效的卫星的位置。在恰当的时候，一个以上的外部指令信号使卫星进行一定程度的重配置，使其适配正被仿效的卫星的上行链路和下行链路频率规划，正确地将所有的上行链路和下行链路天线定向，改变下行链路覆盖区域，改变遥测指令频率（如果需要），使得替换卫星不会干扰邻近的正工作的卫星的功能。

替换卫星的重配置可包括调整 Ku 波段处理装置使得它可以将至少 2 路但少于位于每一路上行链路 Ku 波段中的所有信号导入到任何一个下行链路 Ku 天线，调整来自于至少一个 Ku 波段下行链路天线的下行链路波束，从而将波束指向地球上合适的地点，调整来自于至少一个 C 波段下行链路天线的下行链路波束，从而将波束指向地球上合适的地点，改变来自于至少一个下行链路天线的下行链路波束的覆盖区域，改变至少一个下行链路天线的极性。也可能进行在此描述的其它改变以使卫星能仿效迄今为止的被替换卫星的所有可能的通性能力。

本发明的替换卫星将停留在其移动到的工作位置，直到例如失效的卫星被更换。然后，本发明的卫星将被移动回储存位置或可能被移动到一个新的工作位置且被重配置以替代另一颗已失效或正失效的卫星。

优选地，在 C 波段中和 Ku 波段中，所有的转发机（每一个用于上行链路信道的转发机都能认为在初始滤波器和下变频器后包括放大器）能够在上述两个波段中切换到任何一个下行链路天线，下行链路

天线的极性可以更改。上述两点使得替换卫星能够根据先前建立的被替换的已失效或正失效的卫星下行链路频率规划发送下行链路信号。最好是所有的信号被打成包（包中至少有 2 路信号），这帮助实现本发明的卫星在保持足够的灵活性来满足任何 FSS 卫星的频率规划的同时又切实可行。使用有足够功率的放大器和使用可重配置的下行链路天线进一步使得替换卫星更可行。正如上文解释的，在一些优选实施例中，在 Ku 波段中 12.20 到 12.25GHz 间的 50MHz 波段没有被使用。这简化了卫星的设计，因为上行链路和下行链路 Ku 波段都可以标称的 250MHz 带宽处理，这进一步使得本发明的卫星切实可行。对 Ku 波段使用标准的带宽简化了设计也帮助本发明的卫星变得切实可行。

在一些优选实施例中，替换卫星有一个遥测子系统，它可以在 4 种不同的频率上发射，还有一指令子系统，该子系统能在 4 种不同频率上接收信号，每一个子系统都有不同的频率和可切换的极性。这使替换卫星能被储存且用于很多不同的位置，对三个 ITU 区域中的任何一个都没有干扰，这进一步使本发明的卫星切实可行。

本领域熟练的技术人员可以理解，本发明的卫星在技术上，经济上和其它方面都是切实可行的，同时，为已有的和已计划的大多数（通常至少 75%，合适地至少 85%，较好地至少 90%，最好地至少 95%） FSS 卫星提供有效的备份覆盖区域（也就是，作为一种透明替换）。如权利要求书中使用的，“仿效已有的对地静止的 C 波段和 Ku 波段通信卫星的大部分通信性能”指的就是这一能力。正如将被本领域熟练的技术人员所理解的，仿效通信性能不是说本发明的替换卫星总能被配置来完美地模仿一颗已失效或正失效的卫星的通信性能。因此，正如上面所讨论的，在覆盖区域版图上可能会有一些差异，可能需要对信号进行一些重新分配，将信号分配到不同的信道中。

本领域熟练的技术人员可以理解到，在为已有的和已计划的大多数 FSS 卫星提供有效的备份覆盖区域的同时，本发明的卫星在技术上，

经济上和其它方面都是切实可行的，这可以通过卫星的独特设计而实现，该卫星的特征在于，它是一个各种技术的合成，包括灵活的频率，对 Ku 波段优先使用标准带宽，可独立操纵的上行链路天线，可独立定向的下行链路波束，可独立变化的覆盖区域能修整的下行链路波束，足够功率的放大器，灵活的遥测指令子系统设计，以及能在卫星的设计寿命中做足够次数快速移动的能力。

本发明的通用替换卫星也包括用于处理 BSS（广播卫星业务）通信的装置。

对所有三个 ITU 领域，BSS 上行链路频率波段为 17.3GHz 到 18.1GHz。对于 ITU 领域 I，下行链路 BSS 波段为 11.7 到 12.5GHz，对于 ITU 领域 II，下行链路 BSS 波段为 12.2 到 12.7GHz，对于 ITU 领域 III，下行链路 BSS 波段为 11.7 到 12.2GHz。因此，用于地球的下行链路 Ku 波段在 11.7GHz 到 12.7GHz 的范围内。在此优选使用的下行链路 Ku 波段（如果认为是 4 个下行链路波段）的范围是 10.95-11.20GHZ，11.45-11.70GHz，11.7-12.2GHz 和 12.25-12.75GHz。（正如上面所解释的，12.2 和 12.25GHz 之间的 50MHz 被 ITU 分配用于 Ku 波段下行链路信号，但在此最好不使用。）因此，下行链路 BSS 波段在下行链路 Ku 波段范围内（先前忽略的从 12.2 到 12.25GHz 的 50MHz 除外）。因此，不需要太多的附加设备，本发明的卫星也包括这些装置：用于接收 BSS 信号的装置，将信号下变频到相一 Ku 波段的装置，该装置已存在用于处理 Ku 波段下行链路信号，将已放大和下变频的 BSS 信号放大发回地球的装置。因此，在一个实施例中，本发明的通用替换卫星能够当作一颗备用卫星来处理 BSS 信号和 FSS 信号，尽管每次它只能用作一颗 FSS 或 BSS 卫星的替换卫星。处理 BSS 信号所需的附加装置的设计是本领域熟练的技术人员所公知的。

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(54) Title: UNIVERSAL REPLACEMENT COMMUNICATIONS SATELLITE

(57) Abstract: A practicable universal replacement C band/Ku band communications satellite designed for orbiting the Earth in a storage orbit and a method for its use as a replacement for a failed satellite are disclosed. The universal replacement satellite can be controlled by an external control system (e.g., a ground station) and is reconfigurable by remote command (e.g., from a ground station). The satellite is designed to make several fast moves during its design life from its storage slot to the geostationary slot to which is needs to move when it is to act as a replacement for a failed satellite. The ability to make fast moves helps minimize down time. After its then-current mission of sparing a particular filed satellite has been completed, the communications payload can be turned off and the satellite can be moved back to its storage slot to await its next replacement mission. Various design features allow it to be able to satisfactorily mimic (that is, emulate) the communications capabilities of a very high percentage of the existing geostationary C band and Ku band satellites while still being economically and otherwise practicable. The satellite can also contain means for handling BSS signals so that the satellite can act as a replacement for both FSS and BSS failed satellites.

UNIVERSAL REPLACEMENT COMMUNICATIONS SATELLITE

BACKGROUND OF THE INVENTION

Technical Field

This invention concerns the field of communication satellites and, more specifically, the technical problem of providing a practicable satellite that is capable of acting as a satisfactory replacement satellite for the majority of Fixed Satellite Service ("FSS") communications satellites that are in orbit and desirably also for the majority of such satellites that are to be placed in orbit.

Background

Communications (or telecommunications) satellites have been used for many years. Uplink signals are sent by one or more Earth stations, received by one or more uplink antennas on the satellite, processed by circuitry in the satellite (e.g., frequency-shifted and amplified), sent back (retransmitted) to Earth by one or more downlink antennas on the satellite, and received by one or more Earth stations. The satellites may be placed in various orbits around the Earth. One particularly desirable orbit for certain communications satellites is an equatorial orbit (that is, substantially in the plane of Earth's equator) at an altitude of approximately 22,300 miles (approximately 36,000 kilometers). In that orbit at that altitude, the period of revolution of the satellite around the Earth is equal to the period of rotation of the earth. Accordingly, transmitting (uplink) and receiving (downlink) stations on Earth "see" the satellite remaining at a fixed point in the sky and, thus, the satellite may be considered to be in a geosynchronous equatorial orbit or to be geostationary. As a result, a geostationary satellite's position can be defined by its equatorial longitude. For example, satellites useful for broadcast to the continental United States and its territories may be located from about 69 degrees west longitude to about 139 degrees west longitude.

One advantage of using a geostationary satellite is that the transmitting and receiving stations on Earth do not need to track a satellite in a preselected orbital slot across the sky to maintain the desired uplink and downlink communications characteristics (strength of the signals received by the satellite, footprint of the downlink signals on Earth, etc.). In other words, the antennas on a geostationary satellite can be fixed (or stationary) and the footprints of the downlink antennas can also be fixed.

In addition to typically having fixed antennas, geostationary satellites also typically are designed to receive certain signals on preselected frequency bands (the uplink bands) from one or more preselected geographic areas on Earth according to the uplink frequency plan, to amplify the signals to the desired power level, and to retransmit them

down to Earth on other preselected frequency bands (the downlink bands) to one or more preselected geographic areas on Earth according to the downlink frequency plan.

Unfortunately, as is well-known, there is a significant probability of a malfunction or complete failure during the launch sequence, and even after a successful launch, there may be a problem while trying to deploy the satellite in the desired orbital position (slot). Failures may also occur after the satellite has been successfully positioned in its slot and operated for a period of time. Failures include sudden or gradual, partial or complete loss of telecommunications capability.

In view of the serious economic loss that can result from not having a fully and properly functioning telecommunications satellite operating in its slot throughout the entire expected time period, it is desirable to provide a replacement satellite (i.e., a spare or back-up satellite) that can assume the telecommunications functions of a failed satellite. Replacement satellites may be stored in orbit or on the ground, and each mode of storage has advantages and disadvantages. Regardless of which storage mode is used, because of cost, weight, and other considerations, the replacement satellite will typically be designed for the same uplink and downlink frequency plans, power levels, footprints, telemetry and command subsystem frequencies, etc. as of the satellite for which it is designed to be the spare.

The substantial cost of spare satellites represents a significant expense for providers of satellite communications channels (e.g., organizations owning satellites and leasing their channels for retransmission). That is particularly true because the spare may not ever be needed. Therefore, it would be highly advantageous if such providers could avoid or at least substantially reduce that expense.

Various methods of providing spares have been proposed. See, e.g., U. S. Patent Nos. 3,995,801, 5,120,007, and 5,813,634. Other documents concerning or mentioning spare satellites, back-up coverage, and/or replacing a failing or failed satellite include US 4,502,051, US 5,289,193, US 5,410,731, and PCT WO 98/04017. Other documents concerning communication satellites, communication systems comprising constellations of satellites, communication satellite subsystems and components thereof, and methods of operating communication satellites and systems include U. S. Patent Nos. 4,688,259; 4,858,225; 4,965,587; 5,020,746; 5,175,556; 5,297,134; 5,323,322; 5,355,138; 5,523,997; 5,563,880; 5,860,056; and 5,890,679; EPO Published Application EP 0 915 529 A1; F. Rispoli, "Reconfigurable Satellite Antennas: A Review," Electronic Engineering, volume 61, number 748, pages S22-S27 (April 1989); and Electronics Engineers' Handbook, Section 22-63, "Satellite Communications Systems," pages 22-61 to 22-62 (1975).

Some of those documents concern movable antennas. See, e.g., EP 0 915 529 A1. Some of those documents concern reconfigurable satellites. See, e.g., US 4,688,259; US 4,858,225; US 4,965,587; US 5,175,556; US 5,289,193; US 5,355,138; PCT WO 98/04017; EP 0 915 529 A1; and F. Rispoli: "Reconfigurable Satellite Antennas: A Review," Electronic Engineering, volume 61, number 748, pages S22-S27 (April 1989). Some of those documents concern moving satellites, e.g., from one slot to another or for station-keeping. See, e.g., US 5,020,746; US 5,813,634; and PCT WO 98/04017.

Replacement satellites that are essentially perfect spares (or clones) for essentially all FSS (C band/Ku band) communications satellites may have been considered by others, but, as far as is known, were never built, probably because they were impractical and/or were prohibitively expensive. The problem of providing such a satellite is made all the more complicated by the fact that the conventional C band/Ku band communications satellites have widely differing characteristics concerning, for example, the uplink and downlink communications frequencies used, power levels, and coverage patterns. Furthermore, conventional satellites well before being launched and put in orbit have been designed for particular orbital slots having neighboring satellites with known telemetry and command frequencies and other characteristics.

Accordingly, a long-standing but as yet unsolved technical problem has been to provide practicable but satisfactory replacement satellites for C band/Ku band communications satellites (FSS satellites). In other words, a long-standing but as yet unsolved technical problem has been to provide practicable C band/Ku band replacement satellites that can emulate the performance of a substantial percentage (and preferably a very high percentage) of orbiting C band/Ku band communications satellites while still being technologically, economically, and otherwise practicable.

DISCLOSURE OF THE INVENTION

An invention that solves this technical problem has now been developed. Broadly, in one aspect this invention concerns a universal replacement communications satellite designed for orbiting the Earth in a geostationary orbit, which can be controlled by an external control system, which is reconfigurable, and which can emulate the communications performance of a substantial percentage of existing geostationary C band and Ku band communications satellites and therefore for which it can be a replacement, the universal replacement satellite being designed to receive uplink C band and Ku band signals and to output C band and Ku band downlink signals, the universal replacement communications satellite comprising:

(a) Ku band processing means for (i) receiving Ku band uplink signals in the channels of three 250 MHz uplink bands of 13.75-14.00 GHz, 14.00-14.25 GHz, and 14.25-14.50 GHz, each uplink band having a plurality of uplink Ku band channels,

(ii) amplifying the signals, (iii) down converting their frequencies, and (iv) outputting any of those amplified, reduced-frequency Ku band signals as Ku band downlink signals in the channels of any of six 250 MHz bands within the 10.95-11.20 GHz, 11.45-11.70 GHz, 11.70-12.20 GHz, and 12.25-12.75 GHz downlink Ku bands, each downlink Ku band having a plurality of downlink Ku band channels;

(b) two or more Ku band downlink antennas, each antenna capable of outputting a downlink beam comprising Ku band downlink signals, each downlink beam being separately directable to different locations on Earth;

(c) means for directing the Ku band downlink signals to any one of the two or more Ku band downlink antennas;

(d) C band processing means for (i) receiving C band uplink signals in the channels of two uplink bands of about 5.925 to 6.425 GHz and 6.425 to 6.725 GHz, each uplink band having a plurality of uplink C band channels, (ii) amplifying the signals, (iii) down converting their frequencies, and (iv) outputting those amplified, reduced-frequency C band signals as C band downlink signals in the channels of the 3.70-4.20 GHz and 3.40-3.70 GHz downlink C bands, each downlink C band having a plurality of downlink C band channels;

(e) two or more C band downlink antennas, each antenna capable of outputting a downlink beam comprising downlink C band signals, each downlink beam being separately directable to different locations on Earth;

(f) means for directing the C band downlink signals to any one of the two or more C band downlink antennas;

(g) a propulsion subsystem designed to allow the satellite to make at least three fast moves, each of at least three degrees per day, during the design life of the satellite;

(h) a power subsystem to provide electrical power for satellite operation;

(i) a telemetry and command subsystem to allow the satellite to monitor itself and for communicating with the external control system, the subsystem comprising a telemetry sub-subsystem that can transmit on at least two different frequencies and a command sub-subsystem that can receive on at least two different frequencies;

(j) an attitude and orbit control subsystem for helping to properly orient the satellite with respect to Earth;

(k) a thermal control subsystem for helping to maintain the satellite within the proper temperature range for operation; and

(l) means to reconfigure the satellite, said means comprising (i) means to remotely adjust the Ku band processing means to direct a bundle of at least two but of fewer than all of the signals in each of the uplink Ku bands to any one of the downlink Ku bands, (ii) means to remotely adjust the downlink beam from at least one of the Ku

band downlink antennas to direct the beam to different locations on Earth, (iii) means to remotely adjust the downlink beam from at least one of the C band downlink antennas to direct the beam to different locations on Earth, (iv) means to remotely change the footprint of the downlink beam from at least one of the downlink antennas, and (v) means to remotely change the polarity of at least one of the downlink antennas.

In another aspect this invention concerns a universal replacement communications satellite designed for orbiting the Earth in a geostationary orbit, which can be controlled by an external control system, which is reconfigurable, and which can emulate the communications performance of a substantial percentage of existing geostationary C band and Ku band communications satellites and therefore for which it can be a replacement, the universal replacement satellite being designed to receive uplink C band and Ku band signals and to output C band and Ku band downlink signals, the universal replacement communications satellite comprising:

(a) Ku band processing means for (i) receiving Ku band uplink signals in the channels of three 250 MHz uplink bands of 13.75-14.00 GHz, 14.00-14.25 GHz, and 14.25-14.50 GHz, each uplink band having a plurality of uplink Ku band channels, (ii) amplifying the signals, (iii) down converting their frequencies, and (iv) outputting any of those amplified, reduced-frequency Ku band signals as Ku band downlink signals in the channels of any of six 250 MHz bands within the 10.95-11.20 GHz, 11.45-11.70 GHz, 11.70-12.20 GHz, and 12.25-12.75 GHz downlink Ku bands, each downlink Ku band having a plurality of downlink Ku band channels;

(b) two or more Ku band downlink antennas, each antenna capable of outputting a downlink beam comprising Ku band downlink signals, each downlink beam being separately directable to different locations on Earth;

(c) means for directing the Ku band downlink signals to any one of the two or more Ku band downlink antennas;

(d) C band processing means for (i) receiving C band uplink signals in the channels of two uplink bands of about 5.925 to 6.425 GHz and 6.425 to 6.725 GHz, each uplink band having a plurality of uplink C band channels, (ii) amplifying the signals, (iii) down converting their frequencies, and (iv) outputting those amplified, reduced-frequency C band signals as C band downlink signals in the channels of the 3.70-4.20 GHz and 3.40-3.70 GHz downlink C bands, each downlink C band having a plurality of downlink C band channels;

(e) two or more C band downlink antennas, each antenna capable of outputting a downlink beam comprising downlink C band signals, each downlink beam being separately directable to different locations on Earth;

(f) means for directing the C band downlink signals to any one of the two or more C band downlink antennas;

(g) a propulsion subsystem designed to allow the satellite to make at least three fast moves during the design life of the satellite;

(h) a power subsystem to provide electrical power for satellite operation;

(i) a telemetry and command subsystem to allow the satellite to monitor itself and for communicating with the external control system;

(j) an attitude and orbit control subsystem for helping to properly orient the satellite with respect to Earth;

(k) a thermal control subsystem for helping to maintain the satellite within the proper temperature range for operation; and

(l) means to reconfigure the satellite.

In another aspect this invention concerns a universal replacement communications satellite designed for orbiting the Earth in a geostationary orbit, which can be controlled by an external control system, which is reconfigurable, and which can emulate the communications performance of a substantial percentage of existing geostationary C band and Ku band communications satellites and therefore for which it can be a replacement, the universal replacement satellite being designed to receive uplink C band and Ku band signals and to output C band and Ku band downlink signals, the universal replacement communications satellite comprising:

(a) Ku band processing means for (i) receiving Ku band uplink signals in the channels of three uplink bands, each uplink band having a plurality of uplink Ku band channels, (ii) amplifying the signals, (iii) down converting their frequencies, and (iv) outputting any of those amplified, reduced-frequency Ku band signals as Ku band downlink signals in the channels of any of at least four downlink Ku bands, each downlink Ku band having a plurality of downlink Ku band channels;

(b) two or more Ku band downlink antennas, each antenna capable of outputting a downlink beam comprising Ku band downlink signals, each downlink beam being separately directable to different locations on Earth;

(c) means for directing the Ku band downlink signals to any one of the two or more Ku band downlink antennas;

(d) C band processing means for (i) receiving C band uplink signals in the channels of at least one uplink band, each uplink band having a plurality of uplink C band channels, (ii) amplifying the signals, (iii) down converting their frequencies, and (iv) outputting those amplified, reduced-frequency C band signals as C band downlink signals in the channels of at least one downlink C band, each downlink C band having a plurality of downlink C band channels;

(e) one or more C band downlink antennas, each antenna capable of outputting a downlink beam comprising downlink C band signals, each downlink beam being separately directable to different locations on Earth;

(f) means for directing the C band downlink signals to any one of the one or more C band downlink antennas;

(g) a propulsion subsystem designed to allow the satellite to make at least two fast moves during the design life of the satellite;

(h) a power subsystem to provide electrical power for satellite operation;

(i) a telemetry and command subsystem to allow the satellite to monitor itself and for communicating with the external control system, the subsystem comprising a telemetry sub-subsystem that can transmit on at least two different frequencies and a command sub-subsystem that can receive on at least two different frequencies;

(j) an attitude and orbit control subsystem for helping to properly orient the satellite with respect to Earth;

(k) a thermal control subsystem for helping to maintain the satellite within the proper temperature range for operation; and

(l) means to reconfigure the satellite, said means comprising (i) means to remotely adjust the Ku band processing means to direct a bundle of at least two but of fewer than all of the signals in each of the uplink Ku bands to any one of the downlink Ku bands, (ii) means to remotely adjust the downlink beam from at least one of the Ku band downlink antennas to direct the beam to different locations on Earth, (iii) means to remotely adjust the downlink beam from at least one of the one or more C band downlink antennas to direct the beam to different locations on Earth, (iv) means to remotely change the footprint of the downlink beam from at least one of the downlink antennas, and (v) means to remotely change the polarity of at least one of the downlink antennas.

In some of the preferred embodiments, the C band processing means can output the amplified, reduced-frequency C band signals as C band downlink signals in the channels of either of the 3.70-4.20 GHz and 3.40-3.70 GHz downlink C bands; the Ku band processing means can direct some but not all of the signals in one of the Ku uplink bands to any one of the six 250 MHz downlink Ku bands and can direct other signals in that one of the Ku uplink bands to the same or a different one of the six downlink Ku bands; the means to remotely adjust the Ku band processing means to direct the signals comprises means to remotely adjust the Ku band processing means to change the frequencies to which the signals are down converted; the means for down converting the signals comprises, for example, a frequency synthesizer or fixed oscillators; the satellite has at least two uplink C band antennas and at least two uplink Ku band antennas and all of the uplink antennas are

independently steerable to different locations on Earth; the uplink antennas also function as the downlink antennas; the satellite is designed so that at the start of its design life, the signals of at least thirty-two uplink Ku band channels can be processed by the Ku band processing means and the signals of at least thirty-two uplink C band channels can be processed by the C band processing means; the satellite is designed so that at the end of its design life, the signals of at least twenty-four uplink Ku band channels can be processed by the Ku band processing means and the signals of at least twenty-four uplink C band channels can be processed by the C band processing means; the satellite has means to remotely change the polarity of at least one of the downlink antennas and those means comprise means to remotely change the polarity from linear to circular or vice versa, and/or from vertical to horizontal or vice versa, and/or from clockwise to counterclockwise or vice versa; the means to reconfigure the satellite includes means to remotely adjust the Ku band processing means to direct a bundle of fewer than all of the signals in each of the uplink Ku bands to any one of the downlink Ku bands, for example, two, three, six, or a different number of signals; the satellite has means to remotely change the footprint of the downlink beam from at least one of the Ku band downlink antennas and from at least one of the C band downlink antennas; the downlink beam from at least one of the downlink antennas is independently directable to different locations on Earth; the satellite is designed so that it can make a minimum of three fast moves, each of at least five degrees per day, during the design life of the satellite; the telemetry and command subsystem comprises a telemetry sub-subsystem that can transmit on at least two (preferably four) different frequencies and a command sub-subsystem that can receive on at least two (preferably four) different frequencies; some (or more preferably all) of the Ku band channels are of a standard bandwidth and the standard bandwidth is nominally 36 MHz (which includes some of the channels being 35 MHz wide); and the replacement satellite further comprises BSS band processing means comprising means for (i) receiving BSS uplink signals at frequencies ranging from 17.3 GHz to 18.1 GHz, (ii) amplifying the BSS signals, (iii) down converting their frequencies, and (iv) outputting those amplified, reduced-frequency BSS band signals as BSS downlink signals in the channels of the bands provided for downlink Ku band signals.

In another aspect, the invention concerns a method for replacing a geostationary communications satellite handling C band and Ku band signals, the method comprising providing the universal replacement communications satellite of this invention, placing the replacement satellite in a suitable geostationary slot, and reconfiguring the satellite to emulate the communications performance of the satellite being replaced. The method preferably further includes placing the replacement satellite in a storage orbit whose plane typically will be inclined with respect to the orbital plane of the geostationary slot and

moving the replacement satellite from its storage orbit to the suitable geostationary slot by means of a combined drift and inclination maneuver.

Other features and advantages of the invention will be apparent to those skilled in the art from this disclosure.

MODES FOR CARRYING OUT THE INVENTION

The replacement satellite of this invention is a practicable (technologically, economically, and otherwise) satellite that can emulate the communications performance of the vast majority of existing and future geostationary communications satellites operating in the Fixed Satellite Service (FSS) bands (that is, C band/Ku band communications satellites), as defined by the International Telecommunications Union ("ITU"). The design of the satellite of this invention is generally not critical and any design that has the required features of this invention and allows the benefits of this invention to be achieved may be used.

The design life of the satellite of this invention should be at least 9 years, desirably at least 10 years, more desirably at least 11 years, most desirably at least 12 years, preferably at least 13 years, more preferably at least 14 years, and most preferably at least 15 years. As discussed below, desirably 14 years will be used as the target design life for designing a satellite of this invention that is capable of making 4 "fast moves" of at least 5 degrees (longitudinal Earth equatorial degrees) per day.

Important aspects of the satellite of this invention include its reconfigurability (e.g., it has a reconfigurable communications payload, flexible transponder design, and flexible telemetry and command design), the ability to pick up signals from a variety of locations on Earth and to amplify and retransmit them to a variety of different locations on Earth while tailoring the one or more downlink footprints, and the ability to quickly move from a storage slot to a slot where it is needed (i.e., a slot that allows it to assume the telecommunications functions of the failed or failing satellite).

Broadly, a communications satellite may be thought of as having seven subsystems: structures, power, thermal control, attitude and orbit control, propulsion, telemetry and command, and communications.

The structures subsystem comprises the framework of the satellite on which and in which are mounted the rest of the components of the satellite. The design of the structures subsystem of the satellite of this invention is not critical and is well within the skill of the art once the features of this invention disclosed herein are understood. Broadly speaking, the structures subsystem of the satellite of this invention will be substantially the same as that of a conventional C band/Ku band communications satellite. Large buses are preferred. Thus, for example, buses such as the Lockheed Martin A2100, Loral FS1300, or

the Hughes HS601HP or HS702 may be used. The Loral FS1300 may be preferred for certain embodiments.

The power subsystem comprises the solar panels, which generate electricity and are located on the outside of the satellite, batteries for storing electricity (e.g., electricity generated by the solar panels that is not used at the time of generation), and the distribution network for delivering electricity to the various components of the satellite requiring electrical power. When the solar panels can not provide all of the electricity required, electricity is withdrawn from the batteries. The design of the power subsystem of the satellite of this invention is not critical and is well within the skill of the art once the features of this invention disclosed herein are understood.

Broadly speaking, the power subsystem of the satellite of this invention will be rated at least 8 kilowatts and desirably at least 10 kilowatts. The power subsystem should be capable of providing sufficient power at the end of the design life of the satellite to operate at least 24 channels (transponders) on C band and at least 24 channels (transponders) on Ku band. Preferably, the power subsystem will provide sufficient power to operate at least 30 (desirably at least 32 and preferably at least 36) C band channels and at least 30 (desirably at least 32 and preferably at least 36) Ku band channels at the beginning of the life of the satellite. In the satellite of this invention, the C band channels desirably have a downlink power of about 35-40 watts per channel and the Ku band channels desirably have a downlink power of about 100-150 watts per channel.

The thermal control subsystem helps maintain the operating parts of the satellite within the desired temperature operating range so that the satellite can function properly. Accordingly, some of the heat generated as a byproduct of satellite operations (e.g., by the communications subsystem) will be directed out of the satellite. The design of the thermal control subsystem is not critical and is well within the skill of the art once the features of this invention disclosed herein are understood. The satellite of this invention may use a circulating heat transfer medium (roughly akin to heat pump) to move heat from areas of higher temperature to areas of lower temperature. The satellite may also use heat-radiating surfaces. Broadly speaking, the thermal control subsystem of the satellite of this invention will be similar to the thermal control subsystem of a conventional satellite, the main difference being as follows.

In a conventional C band/Ku band communications satellite, the communications subsystem operates throughout essentially the entire life of the satellite, thereby constantly producing a significant amount of byproduct heat, and the thermal control system is designed accordingly; however, in the satellite of this invention, the communications subsystem typically will operate (and thereby produce byproduct heat) only when the satellite is being used to spare or back-up a failed or failing satellite. Thus,

heaters are provided in the satellite of this invention and operated when the communications subsystem is not being used so as to produce approximately the same amount of heat that the communications subsystem produces when it is operational. That results in keeping the thermal load on the thermal control subsystem approximately constant, thereby simplifying its design.

The attitude and orbit control subsystem helps point the satellite towards the Earth so that the satellite is oriented properly with respect to the Earth. The design of the attitude and orbit control system is not critical and is well within the skill of the art once the features of this invention disclosed herein are understood. Broadly speaking, the attitude and orbit control subsystem of the satellite of this invention will be essentially the same as the attitude and orbit control subsystem of any conventional FSS satellite that has the same size, weight, weight distribution, etc.

The propulsion subsystem of the satellite includes thrusters and a fuel supply. Generally speaking, various forces (for example, from the gravitational effects of the sun and moon, atmospheric drag, the elliptical shape of the earth, and solar radiation) cause a satellite to move from its desired location. Therefore, the satellite's thrusters (engines or motors) are fired (typically at regular intervals) for station-keeping to return the satellite to the desired location, in other words, to control the inclination, eccentricity, and drift of the satellite. By "inclination" is meant the inclination of the plane of the satellite's actual orbit (in degrees of latitude) relative to the plane of the Earth's equator (i.e., the north/south position). "Eccentricity" is the measure of the non-circularity of the satellite orbit, in other words, an indication of the variation in distance between the satellite and the Earth as they move. By "drift" is meant the position of the satellite in an east/west direction, for example, relative to a location on the Earth.

The design of the propulsion subsystem of the satellite of this invention is not critical and is well within the skill of the art once the features of this invention disclosed herein are understood. The geostationary satellites for which the satellite of the present invention can be a replacement are typically three-axis stabilized satellites. Such satellites usually use liquid chemical propulsion systems for station-keeping, for example, with one set of thrusters being used to control inclination and a second set being used to control drift and eccentricity.

Broadly speaking, a conventional satellite does not need to make any "fast moves" because sufficient time usually can be allowed for the satellite to move in an east/west direction or for north/south station-keeping (for example, usually anywhere from 30 to 60 days can be allowed for east/west moves). However, a major difference between the satellite of this invention and a conventional satellite is that the satellite of this invention must be capable of making fast moves. Because the satellite of this invention must be

moved (usually from its storage orbital location) to the equatorial slot required for it to spare or replace a failed or failing satellite, it must be moved to that slot as quickly as possible to minimize down time (i.e., the time when the desired communications capability is not being provided).

The satellite of this invention will typically be allowed to move north and south of the equatorial plane while it is in storage (i.e., is in its storage orbit around the Earth). As is known to those skilled in the art, if a satellite is placed in a geostationary equatorial orbit and there is no station-keeping, the satellite will slowly move either north or south of the equatorial plane, reach a maximum of roughly 8 degrees inclination either above or below the equatorial plane, and then move in the opposite direction until it again reaches a maximum inclination of roughly 8 degrees in the other direction. In other words, if left in storage for a long time without any station-keeping, the satellite of this invention will oscillate slowly over a period of years between an inclination of roughly +8 degrees and -8 degrees.

Under applicable regulations, e.g., Federal Communications Commission ("FCC") regulations, C band/Ku band geostationary satellites must be about 2 longitudinal (east/west) degrees apart. The circumference of the equatorial planar ring around the Earth in which those geostationary satellites are located (at an altitude of about 22,300 miles or 36,000 kilometers) is roughly 160,000 miles (roughly 257,000 kilometers). Therefore, the two longitudinal degrees of separation is equivalent to roughly 800 miles (roughly 1,300 kilometers). Because it will not be cost effective to provide a replacement satellite of this invention near each orbiting C band/Ku band communications satellite that it can spare, it will often be necessary to move the replacement satellite of this invention many thousands of miles (or kilometers) to reach the appropriate slot to spare the failed or failing satellite. Hence, the need for the satellite of this invention to be able to make fast moves.

By a "fast move" is meant a move of at least about 2.5 degrees (longitudinal Earth equatorial degrees) per day, desirably at least 3, more desirably at least 4, most desirably at least 5, preferably at least 6, more preferably at least 7, most preferably at least 8 degrees per day, and sometimes even at least 10 degrees a day.

The satellite of this invention will generally be designed so that during its design life it is capable of making at least 2 fast moves, desirably of at least 3 degrees (longitudinal Earth equatorial degrees) per day, usually at least 3 fast moves of at least 3 degrees per day, desirably at least 3 fast moves of at least 4 degrees per day, more desirably at least 3 fast moves of at least 5 degrees per day, most desirably at least 3 fast moves of at least 6 degrees per day, preferably at least 3 fast moves of at least 7 degrees per day, more preferably at least 3 fast moves of at least 8 degrees per day, sometimes at least 3 fast moves of at least 10 degrees per day, and most preferably at least 4 fast moves of at least 5

degrees per day. Thus, the replacement satellite of this invention will carry substantially more fuel than the typical conventional communications satellite for which it is a spare because it will need to be able to move substantially more quickly than a conventional satellite.

As noted above, desirably 14 years will be used as the target design life for designing a satellite of this invention that is capable of making 4 fast moves of at least 5 degrees (longitudinal Earth equatorial degrees) per day. If the moves (or relocations) made by a satellite of this invention during its lifetime are equivalent to less than that (in other words, less than the equivalent of 4 fast moves of at least 5 degrees per day), the satellite life will be greater than the 14-year design life (assuming no other factor becomes limiting). Because the amount of fuel carried by a satellite of this invention may become the factor that limits the life of the satellite, various techniques for reducing fuel consumption will be used when appropriate, for example, using a "combined drift and inclination maneuver" (described below) to go from the storage (or parking) slot to the slot suitable for replacing (or sparing) the failed or failing satellite and using a slow drift for returning the satellite from the replacement (or sparing) slot to the storage (or parking) location (slot).

Any propulsion subsystem capable of making the required number of fast moves can be used, for example, fluid (e.g., liquid) or solid or plasma systems, e.g., an oxidizer-based system (e.g., one using a hydrazine such as monomethyl hydrazine). Propulsion means that are not powerful enough or otherwise suitable for making the required number of fast moves, e.g., Xenon ion propulsion systems ("XIPS"), may still be used for north/south station-keeping.

Desirably the replacement satellite of this invention can make a combined drift and inclination maneuver while it is moved from its storage location to the slot suitable for backing-up or sparing the failing or failed satellite (the "suitable slot"), thereby reducing the amount of fuel required that would otherwise be required for the move. By "combined drift and inclination maneuver" is meant a maneuver in which the satellite is oriented and its thrusters are fired so that east/west (drift) and north/south (inclination) movement occur simultaneously at some point during the movement from the storage location to the suitable slot. (If the satellite is being used in a first suitable slot to spare a first failed or failing satellite and then is moved to a second suitable slot to spare a second failed or failing satellite, the first suitable slot would be considered to be the storage location from which the replacement satellite was being moved to the second suitable slot.)

The telemetry and command subsystem comprises two sub-subsystems, the telemetry sub-subsystem and the command sub-subsystem. The telemetry sub-subsystem monitors the health of the satellite and transmits the information externally (for example, to a ground control station), and the command sub-subsystem receives commands from outside

the satellite (for example, from a ground control station). The design of the telemetry and command subsystem of the satellite of this invention is not critical and is well within the skill of the art once the features of this invention disclosed herein are understood. Broadly speaking, that subsystem of the satellite of this invention will be substantially the same as that of a conventional C band/Ku band communications satellite, with the following exception.

The typical conventional C band/Ku band communications satellite being spared or replaced by the satellite of this invention is designed to use only one or two frequencies for transmission by the telemetry sub-subsystem and only one or two frequencies for reception by the command sub-subsystem. It is a feature of this invention that the satellite of this invention is designed so that at least two different frequencies (desirably at least three, preferably at least four, and most preferably at least five different frequencies) are available for use and can be used by the telemetry sub-subsystem for transmission and that at least two different frequencies (desirably at least three, preferably at least four, and most preferably at least five different frequencies) are available for use and can be used by the command sub-subsystem for reception. In the satellite of this invention, generally four different frequencies will be available for use by the telemetry sub-subsystem and four different frequencies will be available for use by the command sub-subsystem. Any means known to those skilled in the art can be used to change the frequency in each sub-subsystem, for example, frequency synthesizers or fixed oscillators.

Having so many different frequencies available for each sub-subsystem is important because it allows the frequencies used in a given replacement slot in any ITU region to be selected from the ones that are available in the satellite of this invention so as to avoid interference with, for example, functioning satellites that are near the replacement slot. Desirably the polarization of one or more the telemetry and command antennas can also be switched (e.g., from linear to circular or circular to linear, and/or from vertical to horizontal or from horizontal to vertical, and/or from clockwise to counterclockwise or from counterclockwise to clockwise). That further enhances the ability of the satellite of this invention to avoid interference with, for example, neighboring satellites. Also desirably, one or more of the telemetry and command antennas can be adjusted to improve the quality of the transmission and/or reception. Thus, for example, the beam of the telemetry antenna may be positioned so that the beam reaches different locations on Earth, e.g., by moving the antenna itself and/or by adjusting its transmission beam using means such as a phased array. Similarly, the receiving antenna of the command sub-subsystem may be positioned to point it as different locations on Earth.

Preferably omni (omnidirectional) antennas are the primary antennas used for the telemetry and command subsystem, for the following reason. Typically a conventional

C band/Ku band communications satellite will, once it is in orbit and operational, receive and transmit the telemetry and command signals within the C band or Ku band themselves, and those bands typically use high gain antennas; however, because the satellite of this invention can back-up so many satellites of different designs and those satellites may be at so many different locations throughout the geostationary equatorial plane, the high gain antennas used in the replacement satellite of this invention may be out of view of the ground telemetry and command station(s) customarily used for the replacement satellite. Hence, on the replacement satellite of this invention, omni antennas and not the high gain antennas are preferred for the telemetry and command subsystem.

The communications subsystem receives signals from Earth according to the uplink frequency plan, amplifies them, and retransmits them according to the downlink frequency plan. Design of the communications subsystem of the satellite of this invention is not critical and is well within the skill of the art once the features of this invention disclosed herein are understood.

The communications subsystem of the satellite of this invention is designed to handle C band and Ku band signals. The C band has uplink frequencies in the 6 GHz range and downlink frequencies in the 4 GHz range. The Ku band has uplink frequencies in the 14 GHz frequency range and downlink frequencies in the 12 GHz range.

Broadly speaking, the communications subsystem includes (a) uplink antennas, which receive the uplink communications signals over one or more preselected bands, each band having more than one channel, (b) one or more filters that allow the signals in the preselected bands to pass while blocking any noise or signals at frequencies outside the preselected bands, (c) one or more amplifiers to increase the strength of the desired signals (e.g., to increase the strength of the signals after they leave the one or more filters), (d) a down converter for reducing the uplink frequencies to the downlink frequencies, (e) means for directing the uplink signals (which are received by one or more C band antennas and one or more Ku band antennas) to the appropriate one or more downlink C band antennas and one or more Ku band antennas, and (f) one or more C band antennas and one or more Ku band antennas. The means for directing the signals to the appropriate antennas can include the down converter (which itself may include switches, fixed oscillators, frequency synthesizers, etc., so that the various signals can be down converted to the desired frequencies and those frequencies can be changed), switches, input multiplexers (IMUXs), output multiplexers (output MUXs), etc.

The original C band uplink range allocated by the ITU was 5.925 GHz to 6.425 GHz (a bandwidth of 500 MHz) and the corresponding downlink range was 3.7 GHz to 4.2 GHz (also a bandwidth of 500 MHz). The ITU later made a second band available, namely, 6.425 to 6.725 GHz for the uplink (a bandwidth of 300 MHz) and 3.4 to 3.7 GHz

for the corresponding downlink (also a bandwidth of 300 MHz). More recently a third band for C band uplink signals has been made available, namely, 5.85 GHz to 5.925 GHz (a bandwidth of 75 MHz) but there was no additional band allocated for the downlink. To date, there has been little or no use of this third 75 MHz uplink C band. Thus, C band uplink signals may be in any of the three allocated uplink bands, which happen to be contiguous and occupy 5.85 GHz through 6.725 GHz (a total bandwidth of 875 MHz), and C band downlink signals may be in either of the two allocated downlink bands, which happen to be contiguous and occupy 3.4 GHz through 4.2 GHz (a total bandwidth of 800 MHz).

Principally because of ITU regulations governing which frequencies can be used by C band/Ku band communications satellites in each of the three different ITU regions of the Earth, a satellite handling C band communications will typically operate in only 500 MHz (of the 875 MHz) on the uplink and in only 500 MHz (of the 800 MHz) on the downlink. Thus, a universal replacement satellite must be able to handle at least the 800 MHz of the two earliest uplink C bands from 5.925 GHz through 6.725 GHz (and desirably the entire uplink range of 875 MHz, with the addition of the 75 MHz between 5.85 and 5.925 GHz) and must also be able to handle the entire 800 MHz of the two downlink C bands.

Broadly speaking, within a 500 MHz C band, there will be 24 channels, 12 with one polarization (either vertical or horizontal if linear polarization is used, or either clockwise or counterclockwise if circular polarization is used). Assuming for example that linear polarization is used, each of the 12 vertically polarized channels will be nominally 36 MHz wide, with guard bands between the channels and a guard or buffer band at the top of the 500 MHz range and a guard or buffer band at the bottom of the 500 MHz range. That accounts for the difference between the approximately 41.7 MHz total per channel one calculates by dividing 500 MHz by 12 and the nominal 36 MHz per channel that is usable. The same is true for the 12 horizontally polarized channels. As will be understood by one skilled in the art, the two sets of 12 channels, each channel being nominally 36 MHz wide, can co-exist in the same 500 MHz because the two sets have different polarizations. The same analysis applies for the 24 channels in a band of 500 MHz if circular polarization is used.

For a conventional satellite, the 24 uplink channels may all be transmitted by one or more antennas at substantially the same location on Earth or the channels may be fed by one or more antennas at each of several different locations. Therefore, a conventional satellite designed for a predetermined slot will be designed to capture the 24 channels from all of the transmitting antennas that will be feeding it, and that may require 2 or more uplink antennas. Because the conventional satellite will be in a predetermined slot, the geometry is

known prior to design (i.e., the spatial relationship between the one or more transmitting antennas on Earth and the one or more receiving antennas on the satellite is known) and, accordingly, the position and orientation of each satellite uplink antenna on and to the body of the satellite can be predetermined and fixed.

On the other hand, to allow the replacement satellite of this invention to emulate a substantial percentage of the FSS satellites, some (and desirably all) of its uplink antennas must be independently steerable so that they can adequately capture all of the signals being sent by the transmitting antennas on Earth that were feeding the failed or failing satellite being replaced by the satellite of this invention. The replacement satellite will use at least two uplink C band antennas, possibly at least three, and sometimes at least four. The polarity of at least one (and desirably all) of the C band uplink antennas can be changed to accommodate the pre-established uplink frequency plan of the failed or failing satellite being replaced.

Similar considerations apply to the downlink C bands and the downlink antennas. Thus, in a conventional FSS satellite the C band downlink will be 500 MHz wide, with 24 channels (each nominally 36 MHz wide) polarized either in two groups of vertical and horizontal signals or in two groups of clockwise and counterclockwise signals, and the downlink signals will be aimed at one or more receiving antennas in one or more locations on Earth. Again, because the geometry is known prior to designing a conventional FSS satellite (i.e., that distance and direction between each downlink antenna on the satellite and the desired receiving area or antennas on Earth), the downlink antennas will be fixed in location and orientation on that satellite.

The replacement satellite of this invention will use at least two downlink C band antennas, desirably at least three, preferably at least four, and in some cases at least five. The polarity of at least one (and desirably two, three, four, or more) of the C band downlink antennas can be changed to accommodate the pre-established downlink frequency plan of the failed or failing satellite being replaced. At least some and desirably most of the antennas have sufficient gain with broad coverage. The minimum EIRP (effective isotropic radiated power) for the C band downlink antennas is desirably 36 dbw (decibels with a reference point of a watt).

At least one (and desirably two, three, four, or more) of the C band downlink antennas must have beams that are independently directable so that they can send strong enough signals to all of the antennas on Earth that were receiving signals from the failed or failing satellite being replaced by the satellite of this invention. Directing the beam emanating from an antenna may be accomplished in any appropriate manner, e.g., by steering the antenna itself, by using a multiple beam antenna, by using a phased array antenna, or by using any other type of reconfigurable antenna (see, e.g., US 4,965,587).

In contrast to the C band uplink signal, which may come from only a few antennas (and perhaps as few as just one transmitting antenna on Earth), one or more of the downlink signals may have to be sent to many antennas over a wide area, for example, to the receiving antennas of all of the television cable companies throughout the entire continental United States that carry a particular signal for redistribution to their own customers (e.g., the signal from a nationally distributed movie or sports content provider, which signal is uplinked to a satellite and downlinked from the satellite to cable companies throughout the United States for redistribution by each cable company to its own customers). Alternatively, a particular downlink beam may have to be sent to a rather circumscribed geographic region. Thus, it is desirable that the footprint of at least one (and desirably of two, three, four, or more) of the C band downlink antennas be able to be changed. The footprint of an antenna's downlink beam may be changed using any appropriate means, for example, by steering (moving or redirecting) the antenna and/or by changing the shape of the antenna's beam (e.g., by using a phased array antenna, a reconfigurable antenna, or by any other suitable method).

The entire uplink Ku band occupies 13.75 GHz through 14.5 GHz and may be thought of as having 3 uplink bands, which is each 250 MHz wide and which are contiguous, in other words, one band from 13.75 GHz to 14.00 GHz, a second band from 14.00 GHz to 14.25 GHz, and a third band from 14.25 GHz to 14.50 GHz. In contrast, there are several downlink Ku bands, but only some are contiguous. The first nominal downlink band is at 10.95 GHz to 11.20 GHz (250 MHz bandwidth), the second nominal band runs from 11.45 GHz to 11.70 GHz (250 MHz bandwidth), the third nominal band runs from 11.70 GHz to 12.20 GHz (500 MHz bandwidth), and the fourth nominal band runs from 12.20 GHz to 12.75 GHz (550 MHz bandwidth). The fourth nominal band may itself be considered to comprise two nominal bands, one running from 12.2 to 12.5 GHz, which is a 300 MHz band, and the other running from 12.5 to 12.75 GHz, a 250 MHz band, for a total of 5 bands.

As noted above, the satellite of this invention is practicable, technologically, economically, and otherwise. Practicability has been achieved by carefully determining the features necessary for practicability as opposed to including by rote all features needed for perfect emulation of all existing and future FSS satellites. Thus, although the 50 MHz of bandwidth from 12.20 to 12.25 GHz is part of the spectrum allocated by the ITU for downlink Ku band signals, in some preferred embodiments of the present invention, that 50 MHz will not be used. Thus, in those embodiments, the fourth band will run from 12.25 GHz to 12.75 GHz (a 500 MHz band). Not using the 50 MHz of bandwidth between 12.20 and 12.25 GHz in some preferred embodiments simplifies the design of the satellite of this invention because in those embodiments, all of the uplink and downlink Ku band spectrum

used can be conveniently divided into blocks of 250 MHz (3 uplink 250 MHz bands and 6 downlink 250 bands). That is not the case in those embodiments also utilizing the 50 MHz from 12.20 to 12.25 GHz (because the fourth band used, from 12.20 to 12.75 GHz, would be 550 MHz wide).

Accordingly, viewed one way, in those preferred embodiments not using the 50 MHz from 12.20 to 12.25 GHz, nominally there are 4 downlink Ku bands, two having bandwidths each of 250 MHz and two having bandwidths each of 500 MHz (i.e., 10.95-11.20, 11.45-11.70, 11.7-12.2, and 12.25-12.75 GHz). Viewed another way, in those preferred embodiments, there are 6 downlink Ku bands, each having a bandwidth of 250 MHz. Regardless of how many Ku bands one considers there to be, there is a total of 1550 MHz (1.55 GHz) of non-contiguous bandwidth allocated by the ITU for Ku band downlink signals within the range of 10.95 GHz to 12.75 GHz; however, in some of the preferred embodiments of the present invention, only 1500 MHz (1.5 GHz) will be used.

It will be understood that in the claims, a band from 12.25 to 12.75 GHz, which may be thought of as comprising 2 bands each of 250 MHz, is within a band of 12.20 to 12.75 GHz. Thus, in the claims, "outputting any of those amplified, reduced-frequency Ku band signals as Ku band downlink signals in the channels of any of six 250 MHz bands within the 10.95-11.20 GHz, 11.45-11.70 GHz, 11.70-12.20 GHz, and 12.25-12.75 GHz downlink Ku bands, each downlink Ku band having a plurality of downlink Ku band channels" is not avoided merely by using in addition the 50 MHz between 12.20 and 12.25 GHz.

Principally because of ITU regulations governing which frequencies can be used by C band/Ku band communications satellites in each of the three different ITU regions of the Earth, a satellite handling Ku band communications will typically operate in only 500 MHz (of the 750 MHz allocated) on the uplink and in only 500 MHz (of the 1550 MHz allocated) on the downlink. Thus, a universal replacement satellite must be able to handle all 750 MHz of the uplink Ku bands (which the present invention does) and must also be able to handle most, if not all of the 1550 MHz of allocated downlink Ku band (as noted, in some preferred embodiments of the present invention, only 1500 MHz of the 1550 MHz available will be used).

Broadly speaking, in a satellite of this invention, there will typically be a total for both polarities (i.e., vertical and horizontal, or clockwise and counterclockwise) of 72 Ku band downlink channels available, each nominally 36 MHz wide (1500 MHz divided by 36 for each polarity is approximately 41.7 MHz, and the difference between 41.7 and 36 arises from the presence of guard bands, etc.). Broadly speaking, not more than 750 MHz of downlink Ku bandwidth is used in any one conventional FSS satellite. Accordingly, the satellite of this invention will preferably be designed to power up only 36 channels (total for

both polarities) at start of life (the design point for end of life is 24 channels), although at which frequencies those 36 are powered up will depend upon which conventional FSS satellite is being replaced by the satellite of this invention.

One important feature of the satellite of this invention is that it can receive and direct signals in any one of the three uplink Ku bands to any one of the four nominal downlink Ku bands (or to any one of the five downlink Ku bands if there are considered to be five such bands). Preferably the satellite of this invention can receive and direct signals in any one of the three uplink Ku bands to any one of the six 250 MHz-wide downlink Ku bands. This helps the satellite of this invention emulate the communications performance of the failed or failing C band/Ku band communications satellite that it is replacing.

As with C band, the Ku band channels of a satellite of this invention are each nominally 36 MHz wide, and polarization (linear or circular) desirably is used. Thus, the 500 MHz uplink bandwidth has a total of 24 channels, 12 channels polarized vertically and 12 channels polarized horizontally (or 12 channels polarized clockwise and 12 channels polarized counterclockwise). Considering the 12 vertically polarized channels first, the presence of guard bands between the channels, a guard or buffer band at the top of the 500 MHz range, and a guard or buffer band at the bottom of the 500 MHz range accounts for the difference between the approximately 41.7 MHz total per channel one calculates by dividing 500 MHz by 12 and the nominal 36 MHz per channel that desirably is used in the satellite of this invention. The same is true for the 12 horizontally polarized channels. As will be understood by one skilled in the art, the two sets of 12 channels, each channel being nominally 36 MHz wide, can co-exist in the same 500 MHz because the two sets have different polarizations. The same analysis applies for the 24 channels in a band of 500 MHz if circular polarization is used.

There is no one standard channel bandwidth for the Ku band, and bandwidths of 27, 36, 43, 54, 72, and 108 MHz have been or are being used. Thus, another preferred feature of this invention is that a standard bandwidth is used for the majority of Ku bands (and most preferably for all Ku bands), and most preferably that bandwidth is nominally 36 MHz. For the two non-contiguous downlink Ku bands (i.e., from 10.95 to 11.2 GHz and from 11.45 to 11.70 GHz), the channels preferably are 35 MHz wide, but that width is considered to be within the terms "nominally 36 MHz wide" and "a nominal bandwidth of 36 MHz." Use of a standard bandwidth for all uplink and downlink Ku bands (whether nominally 36 MHz or some other value) allows, for example, filters and multiplexers necessary for handling the other bandwidths to be omitted, thereby simplifying the design and helping to make the satellite of this invention practicable.

As with C band, for a conventional satellite, the 24 uplink channels may all be transmitted by one or more antennas at substantially the same location on Earth or the

channels may be fed by one or more antennas at each of several different locations. Therefore, a conventional satellite designed for a predetermined slot will be designed to capture the 24 Ku band channels from all of the transmitting antennas that will be feeding it (assuming that the preferred nominal bandwidth of 36 MHz is used), and that may require 2 or more uplink antennas. Because the conventional satellite will be in a predetermined slot, the geometry is known prior to design (i.e., the spatial relationship between the one or more transmitting antennas on Earth and the one or more receiving Ku band antennas on the satellite is known) and, accordingly, the position and orientation of each satellite uplink antenna on and to the body of the satellite can be predetermined and fixed.

On the other hand, to allow the replacement satellite of this invention to emulate a substantial percentage of the FSS satellites, some (and desirably all) of its Ku band uplink antennas must be independently steerable so that they can adequately capture all of the signals being sent by the transmitting antennas on Earth that were feeding the failed or failing satellite being replaced by the replacement satellite of this invention. The replacement satellite will use at least two uplink Ku band antennas, possibly at least three, and sometimes at least four. The polarity of at least one (and desirably all) of the Ku band uplink antennas can be changed to accommodate the pre-established uplink frequency plan of the failed or failing satellite being replaced.

In a conventional FSS satellite, the Ku band downlink will be 250, 300, or 500 MHz wide, with channels (each desirably nominally 36 MHz wide) polarized either in two groups of vertical and horizontal signals or in two groups of clockwise and counterclockwise signals, and the downlink signals will be aimed at one or more receiving antennas in one or more locations on Earth. Again, because the geometry is known prior to designing a conventional FSS satellite (i.e., that distance and direction between each downlink Ku band antenna on the satellite and the desired receiving area or antennas on Earth), the downlink antennas will be fixed in location and orientation on that satellite.

The replacement satellite of this invention will use at least two downlink Ku band antennas, desirably at least three, preferably at least four, and in some cases at least five. The polarity of at least one (and desirably two, three, four, or more) of the Ku band downlink antennas can be changed to accommodate the pre-established downlink frequency plan of the failed or failing satellite being replaced. At least some and desirably most of the antennas have sufficient gain with broad coverage. The minimum EIRP (effective isotropic radiated power) for the Ku band downlink antennas is desirably 48 dbw to 50 dbw (spot) at the edge of coverage. The Ku band downlink antennas should have a variety of beam shapes and gain levels, and their design is well within the skill of the art.

At least one (and desirably two, three, four, or more) of the Ku band downlink antennas must have beams that are independently directable so that they can send

strong enough signals to all of the antennas on Earth that were receiving signals from the failed or failing satellite being replaced by the satellite of this invention. As for the C band downlink antennas, directing the beam emanating from a Ku band antenna may be accomplished in any appropriate manner, e.g., by steering the antenna itself, by using a multiple beam antenna, by using a phased array antenna, or by using any other type of reconfigurable antenna (see, e.g., US 4,965,587).

In contrast to the uplink Ku band signals, which may come from only a few antennas (and perhaps as few as just one transmitting antenna on Earth), one or more of the downlink signals may have to be sent to many antennas over a wide area, for example, to the receiving antennas of all of the television cable companies throughout the entire continental United States who carry a particular signal for redistribution to their own customers. Alternatively, a particular downlink beam may have to be sent to a rather circumscribed geographic region. Thus, it is desirable that the footprint of at least one (and desirably of two, three, four, or more) of the Ku band downlink antennas be able to be changed. The footprint of an antenna's downlink beam may be changed using any appropriate means, for example, by steering (moving or redirecting) the antenna and/or by changing the shape of the antenna's beam (e.g., by using a phased array antenna, a reconfigurable antenna, or by any other suitable method).

For example, for one possible embodiment of the satellite of this invention, for the Ku band, one antenna with broad coverage would be used to provide coverage of at least 48 dbw for the continental United States, a section of lower Canada, and the upper portion of Mexico and a spot antenna would be used to provide coverage of at least 42 dbw for Hawaii. With respect to another use of that embodiment of this invention, the satellite being replaced has five Ku band coverage areas, one centered on India at 42 dbw, one centered on China at 42 dbw, one centered on South Africa at 50 dbw, one centered on the Middle East at 42 dbw, and one covering Turkey, northern Africa, and southern Europe at 42 dbw, but the replacement satellite uses four coverage areas, one covering South Africa and countries north of it at 50 dbw, one covering most of India and China at 48 dbw, one covering northern Australia and the area between it and China at 48 dbw, and one covering the Middle East, Turkey, northern Africa, and southern Europe at 48 dbw. The coverage patterns and power levels of the replacement satellite of this invention are not identical to those of the satellite it would replace but are close enough to be considered to satisfactorily mimic or emulate the communications capabilities of that satellite.

With respect to both C band and Ku band, another desirable feature of this invention is that some and preferably all of the uplink and downlink antennas on the replacement satellite are steerable (or movable), both north/south and east/west, by at least 2 degrees from the normal, desirably at least 3 degrees, more desirably at least 4 degrees,

most desirably at least 5 degrees, preferably at least 6 degrees, more preferably at least 7 degrees, and in some cases at least 8 degrees from the normal. In a conventional FSS satellite, the antennas are seldom movable by more than 1 degree north/south or east/west from the normal. The steerability of the antennas of the satellite of this invention helps make that satellite practicable while still allowing it to maintain sufficient flexibility to meet the frequency plans of just about any FSS satellite. The steerability of the downlink antennas may be in addition to means that may be used to direct the beams emanating from the downlink antennas (e.g., phased array or beam forming technology).

As is known, with a conventional FSS satellite, a given signal received by the satellite in a particular C band or Ku band channel may have to be retransmitted along with another uplinked C band or Ku band signal to a particular geographic area. Thus, for example, a first Ku band uplink signal may have to be directed to a Ku band downlink antenna on the satellite serving that geographic area and a second Ku band uplink signal may have to be directed to that same downlink antenna. It may also be the case that the two uplink Ku band signals are on channels having uplink frequencies such that they will require different "amounts" of down conversion to be on the same antenna. It may also be the case that various uplinked signals in a band, perhaps even signals transmitted by the same ground antenna, must be directed to two or more different downlink antennas. Thus, the conventional FSS satellite will be designed with knowledge of the uplink frequency plan (e.g., the location on Earth of each antenna sending the uplink signals, what frequency each signal has) and the downlink frequency plan (e.g., what frequency each signal should have and the location to which the signals have to be sent). That makes it relatively easy to design the down converter, input multiplexers, output multiplexers, etc.

As will be appreciated by one skilled in the art, the numerous existing and planned FSS satellites have many different uplink and downlink frequency plans and many different plans for redirecting the various uplinked signals to the appropriate downlink antennas. It is an important feature of this invention that the replacement satellite can accommodate the wide variety of uplink and downlink frequency plans found in the majority (and preferably the vast majority) of existing and planned FSS satellites.

A perfect clone replacement satellite would contain all the switches, down conversion means, input multiplexers, output multiplexers, etc. needed to allow perfect emulation of all of the uplink and downlink frequency plans in all FSS satellites. For perfect emulation, each uplink signal in the clone would have to be able to be sent to any of the downlink channels without in any way affecting to where any of the other uplink signals was being sent; however, that would make the design impractical (e.g., overly complex) and costly.

In contrast, the satellite of this invention is practicable, technologically, economically, and otherwise. As previously noted, practicability has been achieved by carefully determining the features necessary for practicability as opposed to including by rote all features needed for perfect emulation. Thus, for example, instead of being able to individually and independently switch each uplink signal to any downlink channel in any band, all least some, desirably most, and preferably all of the uplinked signals are switched in bundles. Those bundles contain at least 2 signals each, desirably at least 3, more desirably at least 4, most desirably at least 6, preferably at least 7, more preferably at least 8, and most preferably at least 9. In some preferred embodiments, a bundle will contain 12 signals. Obviously the more signals per bundle, the less the flexibility the processing means (and therefore the satellite) has for emulating FSS satellites. Therefore, in some preferred embodiments, 3 or 6 signals will be bundled. Although not all of the signals in a band need be bundled or need to be in the same size bundles, it is preferred that all signals in a band be bundled and that the bundles have the same size. Thus, for example, for Ku band, for which 36 channels may be used at start of life and for which at least 24 channels may be used at end of life, desirably all signals are bundled and each bundle may contain 3 or 6 signals. As will be understood by one skilled in the art, the fewer the number of signals per bundle, the lesser is the granularity of the processing means.

The down conversion (downward frequency shift) of the frequencies of the uplink signals to the appropriate frequencies for the downlink channels to be used may be made using any means that performs that function and allows the benefits of this invention to be achieved. The design is not critical and is well within the skill of the art once the features of this invention disclosed herein are understood. Thus, means that allow flexibility in down converting the signals are needed. Such means include frequency synthesizers and oscillators (e.g., fixed oscillators) plus switching. Further switching directs the reduced-frequency signals to various input multiplexers where two or more (e.g., preferably 3 or 6) are selected (e.g., by filters) and sent on to amplifiers for boosting their power. The output of the amplifiers is then sent to the output multiplexers where the individual signals are combined for sending to the antennas. As will be understood by one skilled in the art, the particular pathways and equipment and means used for these various tasks is not critical, and any means can be used that performs the necessary functions and allows the benefits of this invention to be achieved. The design of those means is not critical and is well within the skill of the art once the features of this invention disclosed herein are understood.

As will be understood by one skilled in the art, directing a particular uplink signal to a particular downlink antenna will generally involve determining what the downlink frequency is to be for that signal and then converting it to that frequency using the

down conversion means provided in the replacement satellite, which means may be, e.g., a frequency synthesizer or fixed oscillators plus switches. The change in frequency for that first signal (uplink frequency minus downlink frequency) will be of a certain number of Hz. Directing another uplink signal to the same downlink antenna may involve making a change in frequency of a substantially different number of Hz. With the switching and the input and output multiplexers in the replacement satellite, the two uplink signals can be processed so that they are sent to the same downlink antenna. In other words, as a result of this, those signals will be bundled together.

Another important feature of this invention is that it can be remotely reconfigured, that is, signals can be sent from a ground command station to the satellite not only to have the satellite move from its then-current location (which may be in a storage slot) but also to reconfigure it to remotely adjust the Ku band processing means to direct a bundle of at least two but of fewer than all of the signals in each of the uplink Ku bands to any one of the downlink Ku bands, and/or to remotely adjust the downlink beam from at least one of the Ku band downlink antennas to direct the beam to different locations on Earth, and/or to remotely adjust the downlink beam from at least one of the C band downlink antennas to direct the beam to different locations on Earth, and/or to remotely change the footprint of the downlink beam from at least one of the downlink antennas, and/or to remotely change the polarity of at least one of the downlink antennas. The means to cause such reconfiguration, as well as additional changes that are desired (e.g., moving one or more of the uplink antennas) can be any means that performs that function and allows the benefits of this invention to be achieved. The design is not critical and is well within the skill of the art once the features of this invention disclosed herein are understood.

The satellite of this invention may be launched and positioned in a storage orbit using means and techniques known to those skilled in the art. Thus, for example, launch vehicles such as Sea Launch, Ariane, and Proton may be used. The satellite of this invention when first placed in orbit will typically weigh between 4,000 and 5,000 kilograms and more likely between 4,300 and 4,900 kilograms.

The initial storage orbit is typically in a plane inclined to the equatorial plane. As discussed above, the storage plane of the satellite of this invention will slowly oscillate between inclinations of roughly +8 and roughly -8 degrees to the equator unless the satellite is purposely moved. Thus, even though the replacement satellite may initially be placed in a plane inclined to the equator for storage, by the time the replacement satellite is to be moved from its storage orbit to an operational slot, that storage orbit may be in a plane different from the one in which it was initially placed.

Desirably a constellation of at least two (and preferably at least five) universal replacement satellites of this invention will be used. They generally will be stored

in different locations in an east/west direction, although they may not be evenly spaced in an east/west direction. Storing a replacement satellite closer to the conventional satellites for which it is designated to be the replacement usually reduces the amount of communications downtime arising from a failure of the conventional satellite (because the replacement satellite has less distance to travel from the storage slot to the operational slot of the satellite it is replacing).

The satellite of this invention may be launched and placed into an orbital (storage) slot that does not require a separate ITU license. The orbit of the satellite may be allowed to move up and down with respect to the equatorial plane (i.e., become inclined). After a conventional satellite for which the present satellite can act as a back-up fails to an unacceptable degree (which may be anywhere from a partial failure to a complete failure), the appropriate command is sent from outside the replacement satellite (for example, from a ground control station) to the replacement satellite's command sub-subsystem. That results in the satellite moving from its storage slot to the slot in which it will operate to replace the failing or failed satellite. At the appropriate time, one or more external command signal cause reconfiguration of the satellite to the extent necessary, for example, to match the uplink and downlink frequency plans of the satellite being emulated, to correctly position all of the uplink and downlink antennas, to change the downlink footprints, and to change the telemetry and command frequencies (if necessary) so that the replacement satellite will not interfere with the functioning of adjacent operating satellites.

The reconfiguration of the replacement satellite can include adjusting the Ku band processing means so that it can direct a bundle of at least two but of fewer than all of the signals in each of the uplink Ku bands to any one of the downlink Ku bands, adjusting the downlink beam from at least one of the Ku band downlink antennas to direct the beam to the appropriate location on Earth, adjusting the downlink beam from at least one of the C band downlink antennas to direct the beam to different locations on Earth, changing the footprint of the downlink beam from at least one of the downlink antennas, and changing the polarity of at least one of the downlink antennas. The other changes described herein may also be made so that the satellite can emulate insofar as is possible the communications capabilities of the satellite being replaced.

The replacement satellite of this invention will stay in the operational slot to which it has been moved until, for example, the failed satellite is replaced. The replacement satellite of this invention will then be moved back to a storage slot or possibly moved to a new operational slot and reconfigured to spare another failed or failing satellite.

Preferably within C band and within Ku band all of the transponders (each of which for an uplink channel may be thought of as comprising the amplifier after the initial filter and the down converter) can be switched to any of the downlink antennas within that

band and the polarizations of the downlink antennas can be varied. Both of those allow the replacement satellite to transmit downlink signals in accordance with the previously established downlink frequency plan for the failed or failing satellite being replaced. The fact that preferably all the signals are bundled (in bundles of at least 2 signals) helps make the satellite of this invention practicable while still maintaining sufficient flexibility to meet the frequency plans of just about any FSS satellite. The use of amplifiers of sufficient power and the use of reconfigurable downlink antennas further makes the replacement satellite practicable. As explained above, in some preferred embodiments, the 50 MHz between 12.20 and 12.25 GHz in the Ku band is not used. That simplifies the design of the satellite because both the uplink and the downlink Ku bands can be dealt with in standard size bands of 250 MHz, there further making the satellite of this invention practicable. The use of a standardized bandwidth for the Ku band simplifies the design and also helps make the satellite of this invention practicable.

In some preferred embodiments, the replacement satellite has a telemetry sub-subsystem that can transmit on four different frequencies and a command sub-subsystem that can receive on four different frequencies, each with variable frequencies and switchable polarizations. That allows the replacement satellite to be stored and to be used in a wide variety of slots without frequency interference in any of the three ITU regions, further making the satellite of this invention practicable.

As will be appreciated by those skilled in the art, the satellite of this invention is technologically, economically, and otherwise practicable while still providing effective back-up coverage (that is, acting as a virtually transparent replacement) for the majority (generally at least 75%, desirably at least 85%, preferably at least 90%, and most preferably at least 95%) of existing and planned FSS satellites. As used in the claims, "emulate the communications performance of a substantial percentage of existing geostationary C band and Ku band communications satellites" refers to this capability. As will be appreciated by one skilled in the art, emulating the communications performance does not mean that the replacement satellite of this invention can always be reconfigured to perfectly mimic the communications performance of a failed or failing satellite. Thus, as discussed above, there may be a difference in coverage patterns and some reassignment of signals to different channels may be necessary.

As will also be appreciated by those skilled in the art, that the satellite of this invention is technologically, economically, and otherwise practicable while still providing effective back-up coverage for the majority of existing and planned FSS satellites is made possible by the unique design of the satellite, which features a combination of frequency agility, the preferred use of a standard bandwidth for the Ku band, independently steerable uplink antennas, independently directable downlink beams, independently variable

downlink beams whose footprints can be tailored, amplifiers of sufficient power, flexible telemetry and command design, and the ability to make a sufficient number of fast moves over the satellite's design life.

The universal replacement satellite of this invention may also contain means for handling BSS (broadcast satellite services) communications.

For all three ITU regions, the BSS uplink frequency band is 17.3 GHz to 18.1 GHz. For ITU Region I, the downlink BSS band is 11.7 to 12.5 GHz, for Region II the downlink BSS band is 12.2 to 12.7 GHz, and for Region III the downlink BSS band is 11.7 to 12.2 GHz. Thus, the downlink BSS bands for Earth are within the range of 11.7 GHz to 12.7 GHz. The ranges for the downlink Ku bands (if considered to be four downlink bands) preferably used herein are 10.95-11.20 GHz, 11.45-11.70 GHz, 11.7-12.2 GHz, and 12.25-12.75 GHz. (As explained above, the 50 MHz between 12.2 and 12.25 MHz is allocated by the ITU for use for Ku band downlink signals but preferably is not used herein.) Thus, the downlink BSS bands are within the scope of the downlink Ku bands (except for the preferred omission of the 50 MHz between 12.2 and 12.25 GHz). Therefore, with not too much additional equipment, the satellite of this invention may also contain means for receiving BSS signals, down converting their signals to the same Ku bands already present for handling Ku band downlink signals, amplifying, and transmitting the down converted, amplified BSS signals back to Earth. Thus, in one embodiment, the universal replacement satellite of this invention will be able to act as a spare to handle BSS signals and FSS signals although at any one time it may be used to act as a replacement for only an FSS or a BSS satellite. The design of the additional means needed to handle BSS signals is well within the skill of the art.

CLAIMS

1. A universal replacement communications satellite designed for orbiting the Earth in a geostationary orbit, which can be controlled by an external control system, which is reconfigurable, and which can emulate the communications performance of a substantial percentage of existing geostationary C band and Ku band communications satellites and therefore for which it can be a replacement, the universal replacement satellite being designed to receive uplink C band and Ku band signals and to output C band and Ku band downlink signals, the universal replacement communications satellite comprising:

   (a) Ku band processing means for (i) receiving Ku band uplink signals in the channels of three uplink bands, each uplink band having a plurality of uplink Ku band channels, (ii) amplifying the signals, (iii) down converting their frequencies, and (iv) outputting any of those amplified, reduced-frequency Ku band signals as Ku band downlink signals in the channels of any of at least four downlink Ku bands, each downlink Ku band having a plurality of downlink Ku band channels;

   (b) two or more Ku band downlink antennas, each antenna capable of outputting a downlink beam comprising Ku band downlink signals, each downlink beam being separately directable to different locations on Earth;

   (c) means for directing the Ku band downlink signals to any one of the two or more Ku band downlink antennas;

   (d) C band processing means for (i) receiving C band uplink signals in the channels of at least one uplink band, each uplink band having a plurality of uplink C band channels, (ii) amplifying the signals, (iii) down converting their frequencies, and (iv) outputting those amplified, reduced-frequency C band signals as C band downlink signals in the channels of at least one downlink C band, each downlink C band having a plurality of downlink C band channels;

   (e) one or more C band downlink antennas, each antenna capable of outputting a downlink beam comprising downlink C band signals, each downlink beam being separately directable to different locations on Earth;

   (f) means for directing the C band downlink signals to any one of the one or more C band downlink antennas;

   (g) a propulsion subsystem designed to allow the satellite to make at least two fast moves during the design life of the satellite;

   (h) a power subsystem to provide electrical power for satellite operation;

(i) a telemetry and command subsystem to allow the satellite to monitor itself and for communicating with the external control system;

(j) an attitude and orbit control subsystem for helping to properly orient the satellite with respect to Earth;

(k) a thermal control subsystem for helping to maintain the satellite within the proper temperature range for operation; and

(l) means to reconfigure the satellite.

2. The universal replacement satellite of claim 1 in which the Ku band processing means is Ku band processing means for (a) receiving Ku band uplink signals in the channels of three 250 MHz uplink bands of 13.75-14.00 GHz, 14.00-14.25 GHz, and 14.25-14.50 GHz, each uplink band having a plurality of uplink Ku band channels, (b) amplifying the signals, (c) down converting their frequencies, and (d) outputting any of those amplified, reduced-frequency Ku band signals as Ku band downlink signals in the channels of any of six 250 MHz bands within the 10.95-11.20 GHz, 11.45-11.70 GHz, 11.70-12.20 GHz, and 12.25-12.75 GHz downlink Ku bands, each downlink Ku band having a plurality of downlink Ku band channels.

3. The universal replacement satellite of claim 2 in which the means to reconfigure the satellite includes means to remotely adjust the Ku band processing means to direct some but not all of the signals in one of the Ku uplink bands to any one of the six downlink Ku bands and to direct other signals in that one of the Ku uplink bands to the same or a different one of the six downlink Ku bands.

4. The replacement satellite of 3 in which the means to remotely adjust the Ku band processing means to direct the signals comprises means to remotely adjust the Ku band processing means to change the frequencies to which the signals are down converted.

5. The universal replacement satellite of any preceding claim in which the C band processing means is C band processing means for (a) receiving C band uplink signals in the channels of two uplink bands of 5.925 to 6.425 GHz and 6.425 to 6.725 GHz, each uplink band having a plurality of uplink C band channels, (b) amplifying the signals, (c) down converting their frequencies, and (d) outputting those amplified, reduced-frequency C band signals as C band downlink signals in the channels of the 3.70-4.20 GHz and 3.40-3.70 GHz downlink C bands, each downlink C band having a plurality of downlink C band channels.

6. The universal replacement satellite of any preceding claim in which (a) there are two or more C band downlink antennas, each antenna capable of outputting a downlink beam comprising downlink C band signals, each downlink beam being separately

directable to different locations on Earth, and (b) there are means for directing the C band downlink signals to any one of the two or more C band downlink antennas.

7. The universal replacement satellite of any preceding claim in which the propulsion subsystem is designed to allow the satellite to make at least three fast moves during the design life of the satellite, each of at least 3 degrees per day.

8. The universal replacement satellite of any preceding claim in which the telemetry and command subsystem comprises a telemetry sub-subsystem that can transmit on at least two different frequencies and a command sub-subsystem that can receive on at least two different frequencies.

9. The universal replacement satellite of any preceding claim in which the means to reconfigure the satellite comprises (a) means to remotely adjust the Ku band processing means to direct a bundle of at least two but of fewer than all of the signals in each of the uplink Ku bands to any one of the downlink Ku bands, (b) means to remotely adjust the downlink beam from at least one of the Ku band downlink antennas to direct the beam to different locations on Earth, (c) means to remotely adjust the downlink beam from at least one of the one or more C band downlink antennas to direct the beam to different locations on Earth, (d) means to remotely change the footprint of the downlink beam from at least one of the downlink antennas, and (e) means to remotely change the polarity of at least one of the downlink antennas.

10. The replacement satellite of any of claims 1, 2, and 5 to 9 in which the means to reconfigure the satellite includes means to remotely adjust the Ku band processing means to direct some but not all of the signals in one of the Ku uplink bands to any one of the at least four downlink Ku bands and to direct other signals in that one of the Ku uplink bands to the same or a different one of the at least four downlink Ku bands.

11. The replacement satellite of claim 10 in which the means to remotely adjust the Ku band processing means to direct the signals comprises means to remotely adjust the Ku band processing means to change the frequencies to which the signals are down converted.

12. The replacement satellite of any preceding claim further comprising one or more uplink C band antennas and one or more uplink Ku band antennas, all of the uplink antennas being independently steerable to different locations on Earth.

13. The replacement satellite of any preceding claim in which the uplink antennas also function as the downlink antennas.

14. The replacement satellite of any preceding claim wherein it is designed so that at the end of its design life, the signals of at least twenty-four uplink Ku band channels can

be processed by the Ku band processing means and the signals of at least twenty-four uplink C band channels can be processed by the C band processing means.

15. The replacement satellite of any preceding claim further comprising means to remotely change the footprint of the downlink beam from at least one of the Ku band downlink antennas.

16. The replacement satellite of any preceding claim in which the propulsion system is designed to allow the satellite to make at least three fast moves, each of at least five degrees per day, during the design life of the satellite.

17. The replacement satellite of any preceding claim wherein it is designed so that at the start of its design life, the signals of at least thirty-two uplink Ku band channels can be processed by the Ku band processing means and the signals of at least thirty-two uplink C band channels can be processed by the C band processing means.

18. The replacement satellite of any preceding claim in which all of the Ku band channels have a standard bandwidth.

19. The replacement satellite of claim 18 in which the standard bandwidth is nominally 36 MHz.

20. The replacement satellite of any preceding claim further comprising BSS band processing means comprising means for (a) receiving BSS uplink signals at frequencies ranging from 17.3 GHz to 18.1 GHz, (b) amplifying the BSS signals, (iii) down converting their frequencies, and (c) outputting those amplified, reduced-frequency BSS band signals as BSS downlink signals in the channels of the bands provided for downlink Ku band signals.

21. A universal replacement communications satellite designed for orbiting the Earth in a geostationary orbit, which can be controlled by an external control system, which is reconfigurable, and which can emulate the communications performance of a substantial percentage of existing geostationary C band and Ku band communications satellites and therefore for which it can be a replacement, the universal replacement satellite being designed to receive uplink C band and Ku band signals and to output C band and Ku band downlink signals, the universal replacement communications satellite comprising:

(a) Ku band processing means for (i) receiving Ku band uplink signals in the channels of three 250 MHz uplink bands of 13.75-14.00 GHz, 14.00-14.25 GHz, and 14.25-14.50 GHz, each uplink band having a plurality of uplink Ku band channels, (ii) amplifying the signals, (iii) down converting their frequencies, and (iv) outputting any of those amplified, reduced-frequency Ku band signals as Ku band downlink signals in the channels of any of six 250 MHz bands within the 10.95-11.20 GHz, 11.45-11.70 GHz, 11.70-12.20

GHz, and 12.25-12.75 GHz downlink Ku bands, each downlink Ku band having a plurality of downlink Ku band channels;

(b) two or more Ku band downlink antennas, each antenna capable of outputting a downlink beam comprising Ku band downlink signals, each downlink beam being separately directable to different locations on Earth;

(c) means for directing the Ku band downlink signals to any one of the two or more Ku band downlink antennas;

(d) C band processing means for (i) receiving C band uplink signals in the channels of two uplink bands of 5.925 to 6.425 GHz and 6.425 to 6.725 GHz, each uplink band having a plurality of uplink C band channels, (ii) amplifying the signals, (iii) down converting their frequencies, and (iv) outputting those amplified, reduced-frequency C band signals as C band downlink signals in the channels of the 3.70-4.20 GHz and 3.40-3.70 GHz downlink C bands, each downlink C band having a plurality of downlink C band channels;

(e) two or more C band downlink antennas, each antenna capable of outputting a downlink beam comprising downlink C band signals, each downlink beam being separately directable to different locations on Earth;

(f) means for directing the C band downlink signals to any one of the two or more C band downlink antennas;

(g) a propulsion subsystem designed to allow the satellite to make at least three fast moves, each of at least three degrees per day, during the design life of the satellite;

(h) a power subsystem to provide electrical power for satellite operation;

(i) a telemetry and command subsystem to allow the satellite to monitor itself and for communicating with the external control system, the subsystem comprising a telemetry sub-subsystem that can transmit on at least two different frequencies and a command sub-subsystem that can receive on at least two different frequencies;

(j) an attitude and orbit control subsystem for helping to properly orient the satellite with respect to Earth;

(k) a thermal control subsystem for helping to maintain the satellite within the proper temperature range for operation; and

(l) means to reconfigure the satellite, said means comprising (i) means to remotely adjust the Ku band processing means to direct a bundle of at least two but of fewer than all of the signals in each of the uplink Ku bands to any one of the downlink Ku bands, (ii) means to remotely adjust the downlink

beam from at least one of the Ku band downlink antennas to direct the beam to different locations on Earth, (iii) means to remotely adjust the downlink beam from at least one of the C band downlink antennas to direct the beam to different locations on Earth, (iv) means to remotely change the footprint of the downlink beam from at least one of the downlink antennas, and (v) means to remotely change the polarity of at least one of the downlink antennas.

22. A universal replacement communications satellite designed for orbiting the Earth in a geostationary orbit, which can be controlled by an external control system, which is reconfigurable, and which can emulate the communications performance of a substantial percentage of existing geostationary C band and Ku band communications satellites and therefore for which it can be a replacement, the universal replacement satellite being designed to receive uplink C band and Ku band signals and to output C band and Ku band downlink signals, the universal replacement communications satellite comprising:

(a) Ku band processing means for (i) receiving Ku band uplink signals in the channels of three 250 MHz uplink bands of 13.75-14.00 GHz, 14.00-14.25 GHz, and 14.25-14.50 GHz, each uplink band having a plurality of uplink Ku band channels, (ii) amplifying the signals, (iii) down converting their frequencies, and (iv) outputting any of those amplified, reduced-frequency Ku band signals as Ku band downlink signals in the channels of any of six 250 MHz bands within the 10.95-11.20 GHz, 11.45-11.70 GHz, 11.70-12.20 GHz, and 12.25-12.75 GHz downlink Ku bands, each downlink Ku band having a plurality of downlink Ku band channels;

(b) two or more Ku band downlink antennas, each antenna capable of outputting a downlink beam comprising Ku band downlink signals, each downlink beam being separately directable to different locations on Earth;

(c) means for directing the Ku band downlink signals to any one of the two or more Ku band downlink antennas;

(d) C band processing means for (i) receiving C band uplink signals in the channels of two uplink bands of about 5.925 to 6.425 GHz and 6.425 to 6.725 GHz, each uplink band having a plurality of uplink C band channels, (ii) amplifying the signals, (iii) down converting their frequencies, and (iv) outputting those amplified, reduced-frequency C band signals as C band downlink signals in the channels of the 3.70-4.20 GHz and 3.40-3.70 GHz downlink C bands, each downlink C band having a plurality of downlink C band channels;

(e) two or more C band downlink antennas, each antenna capable of outputting a downlink beam comprising downlink C band signals, each downlink beam being separately directable to different locations on Earth;

(f) means for directing the C band downlink signals to any one of the two or more C band downlink antennas;

(g) a propulsion subsystem designed to allow the satellite to make at least three fast moves during the design life of the satellite;

(h) a power subsystem to provide electrical power for satellite operation;

(i) a telemetry and command subsystem to allow the satellite to monitor itself and for communicating with the external control system;

(j) an attitude and orbit control subsystem for helping to properly orient the satellite with respect to Earth;

(k) a thermal control subsystem for helping to maintain the satellite within the proper temperature range for operation; and

(l) means to reconfigure the satellite.

23. A method for replacing a geostationary communications satellite handling C band and Ku band signals, the method comprising providing the universal replacement communications satellite of any preceding claim, placing the replacement satellite in a suitable geostationary slot, and reconfiguring the satellite to emulate the communications performance of the satellite being replaced.

24. The method of claim 23 further comprising placing the replacement satellite in a storage orbit and moving the replacement satellite from its storage orbit to the suitable geostationary slot by means of a combined drift and inclination maneuver.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/12011

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H04B 1/00
US CL : 455/12.1, 13.1, 427
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 455/12.1, 13.1, 13.2, 13.3, 427

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,152,482 A (PERKINS) 06 October 1992, entire document	1-24
A	US 5,779,195 A (BASUTHAKUR ET AL.) 14 July 1998, entire document	1-24
A	WO 98/04017 A1 (LOCKE ET AL.) 29 January 1998, entire document	1-24
A	US 5,896,558 A (WIEDEMAN) 20 April 1999, entire document	1-24
A,P	US 5,929,804 A (JONES ET AL.) 27 July, 1999, entire document	1-24
A,P	US 5,978,370 A (SHIVELY) 02 November 1999, entire document	1-24

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 AUGUST 2000	29 AUG 2000

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